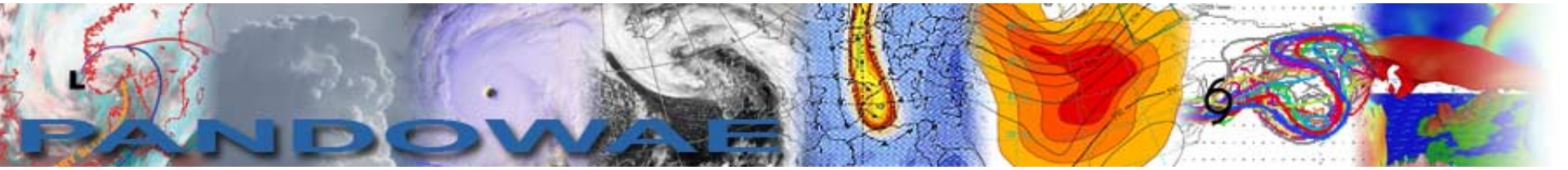
2014-08

The influence of tropical cyclones on the predictability of midlatitude weather systems

Jones, Sarah

Karlsruhe Institute of Technology



The influence of tropical cyclones on the predictability of midlatitude weather systems

Sarah Jones [1,2], Doris Anwender [1,3], Pat Harr[4], Simon Lang[1,5], Martin Leutbecher[5], Melinda Peng[6], Carolyn Reynolds[6]

[1] Deutscher Wetterdienst, [2] Karlsruhe Insitut für Technologie , [3] MunichRe, [4]Naval Postgraduate School, [5]ECMWF, [6] Naval Research Laboratory

PANDOWAE – Predictability and Dynamics of Weather Systems in the Atlantic–European Sector (FOR896) is a research unit of the German Research Council (DFG)

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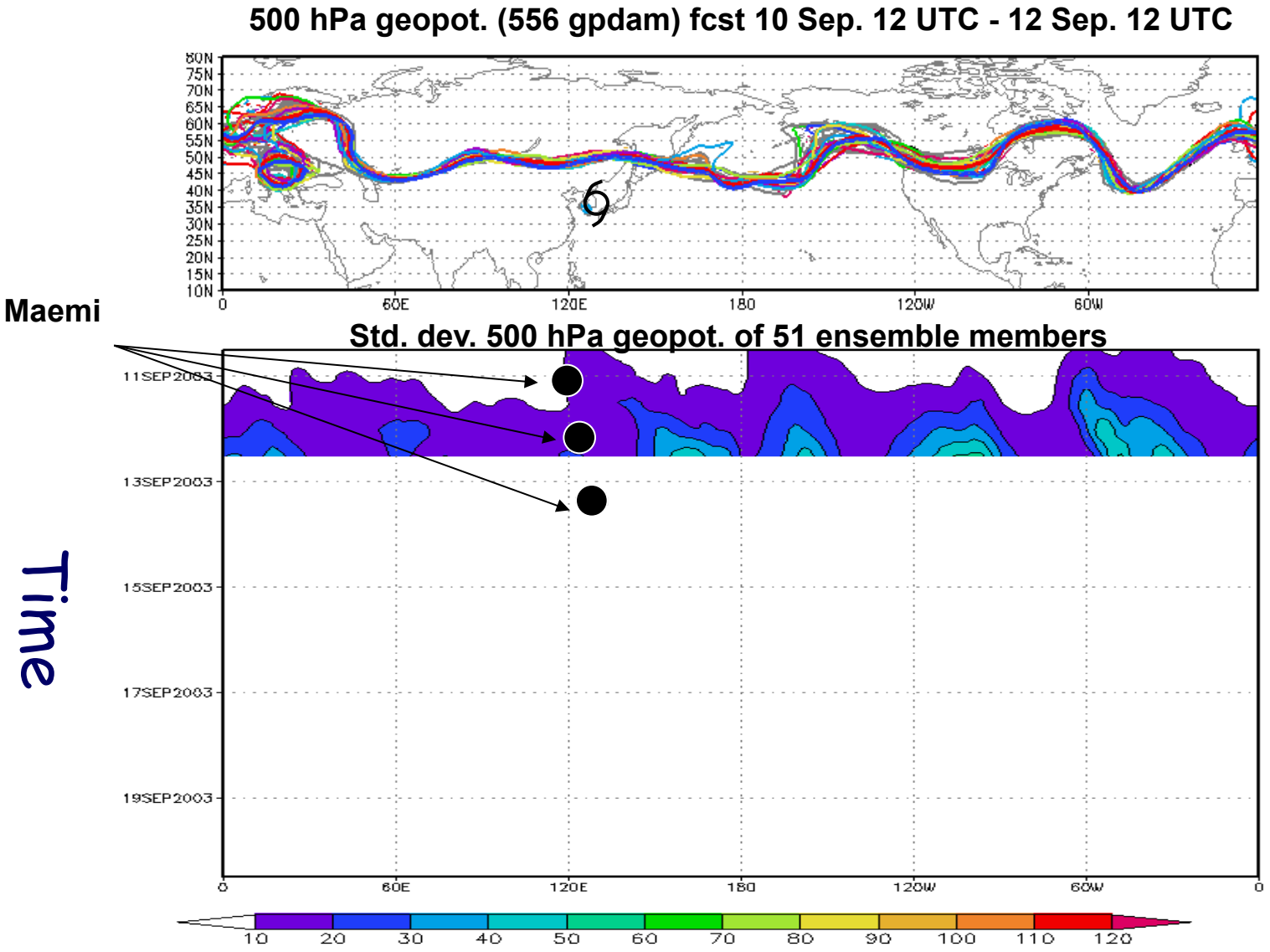
Spagetti plot of 500 hPa geopotential (top) and Hovmöller of 500 hPa Standard deviation of the ensemble members (bottom)



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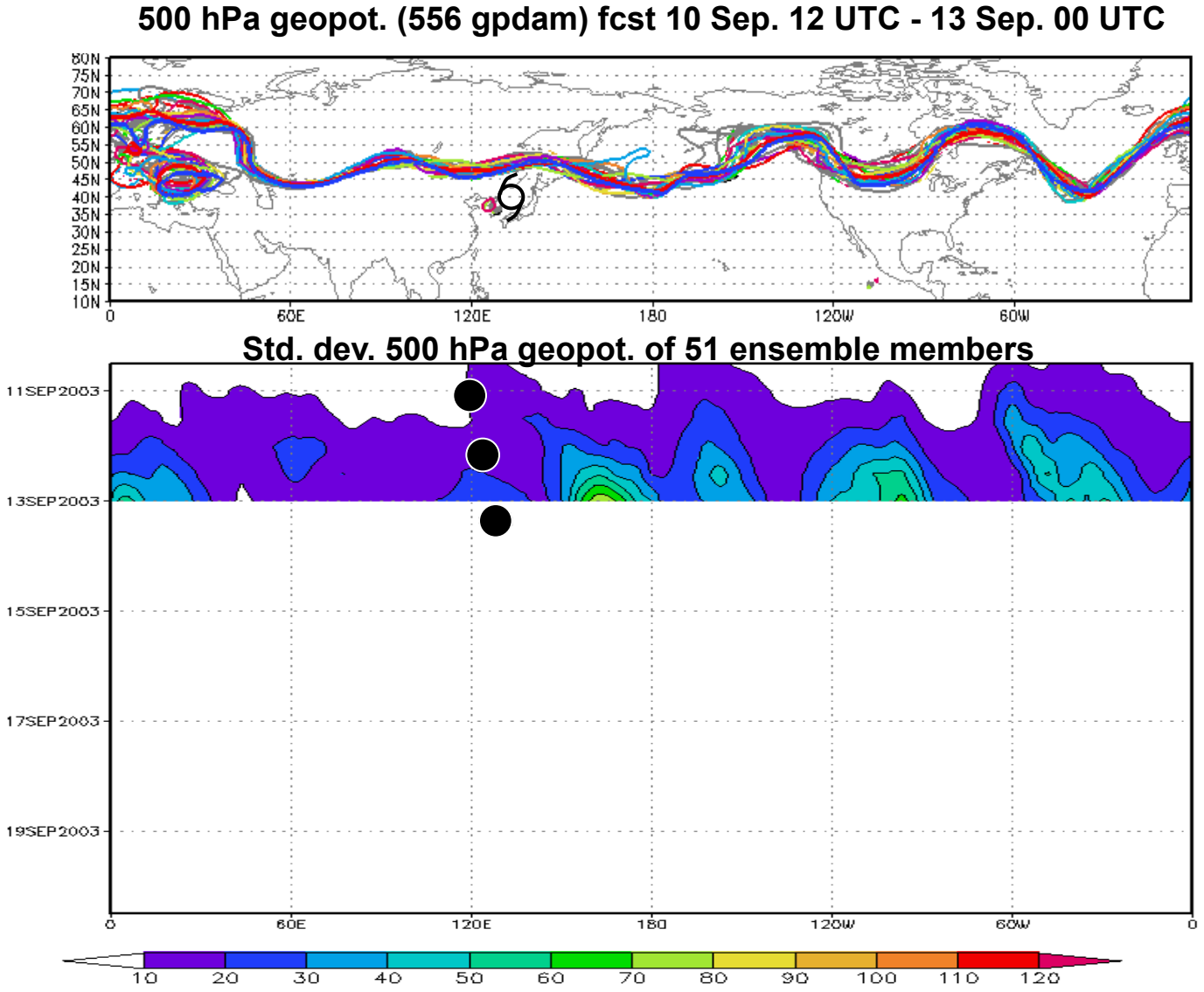

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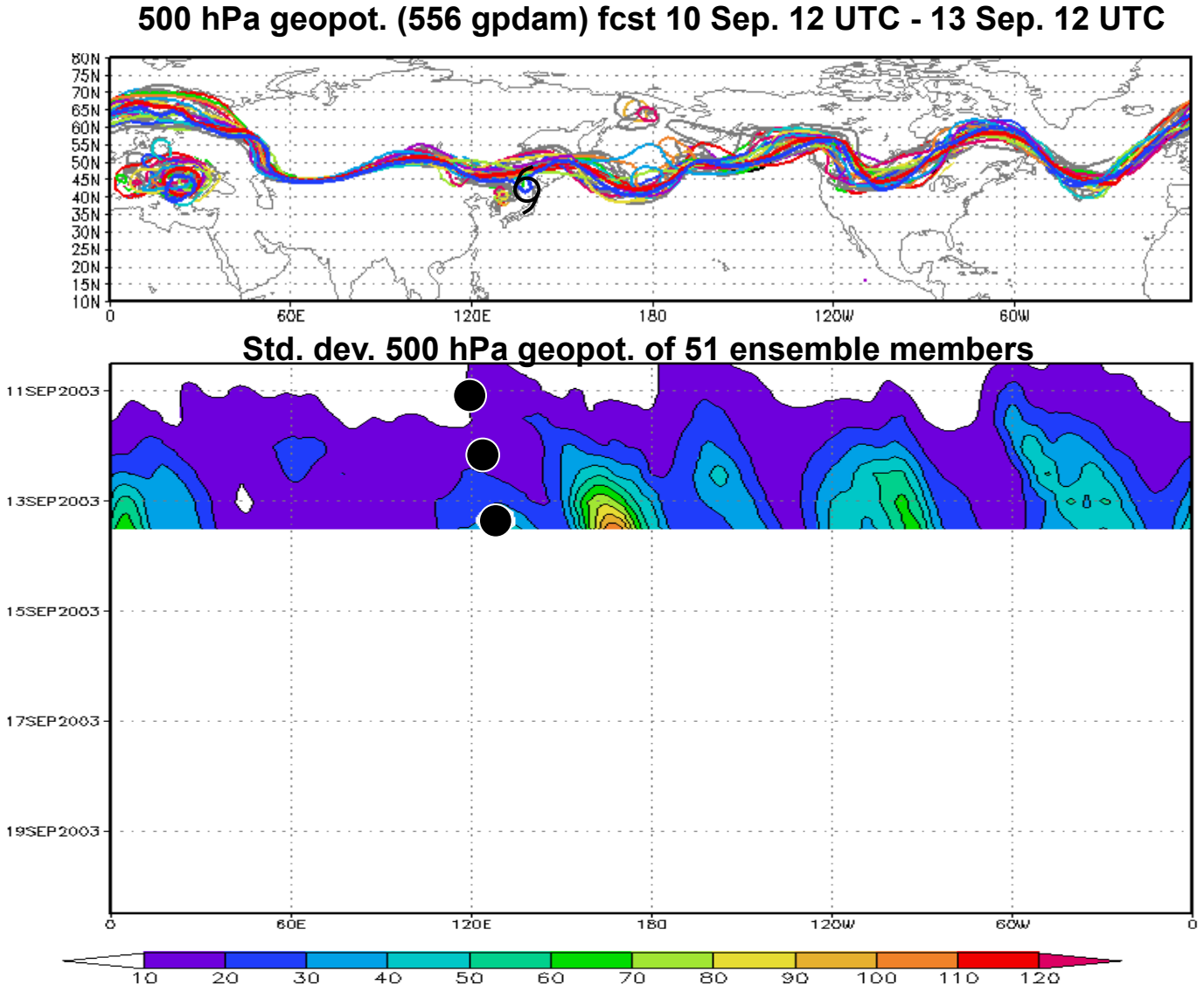

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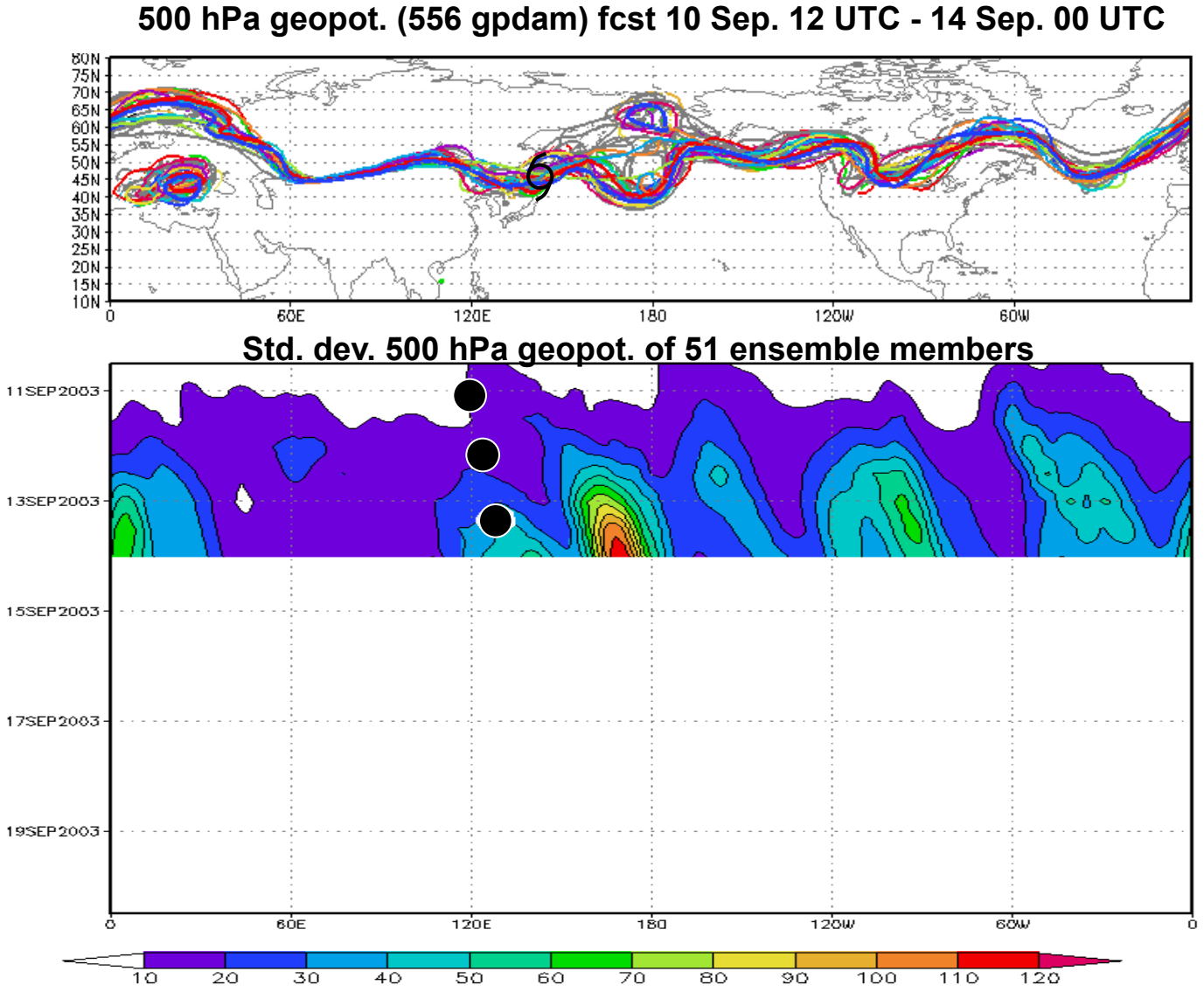

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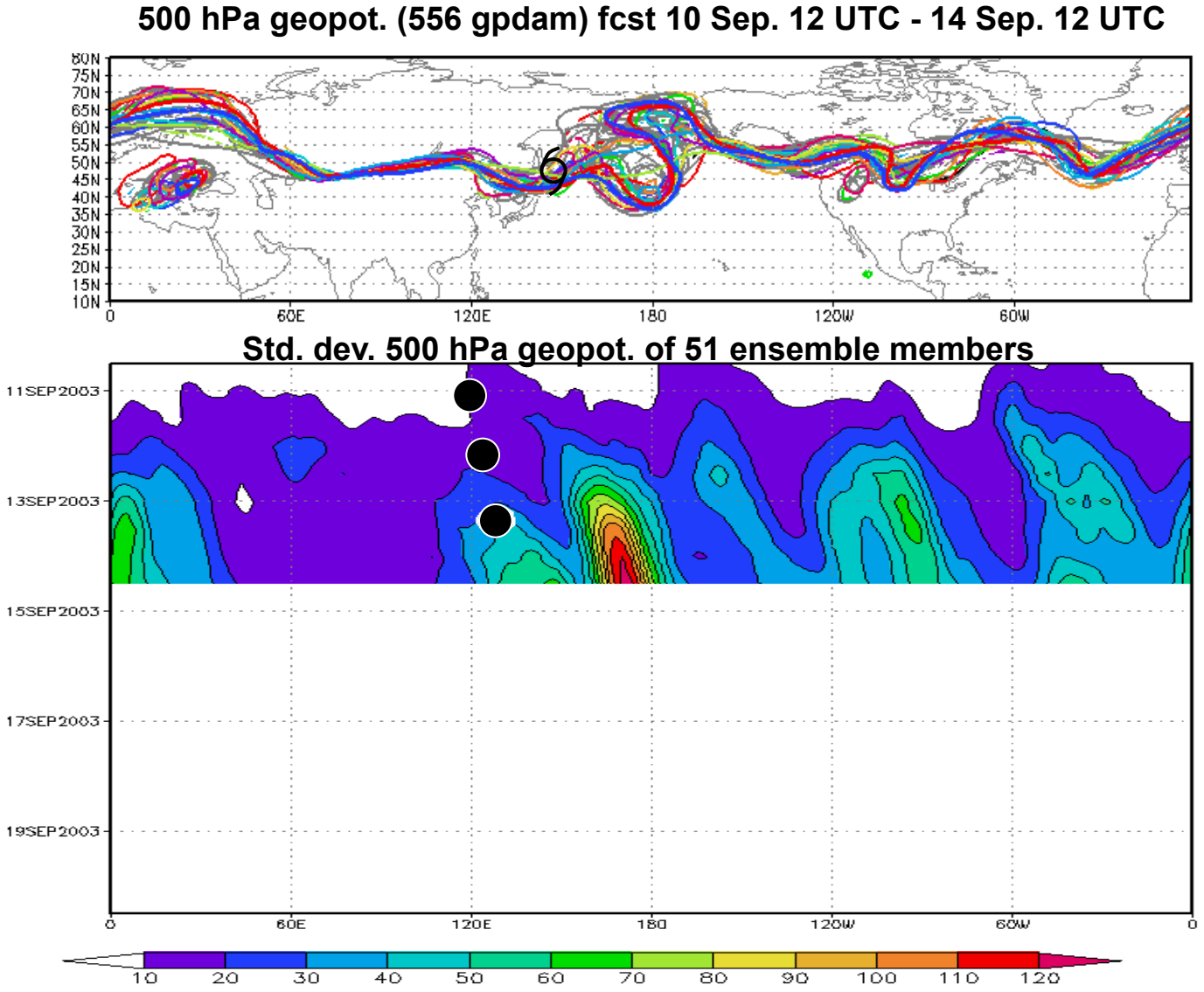

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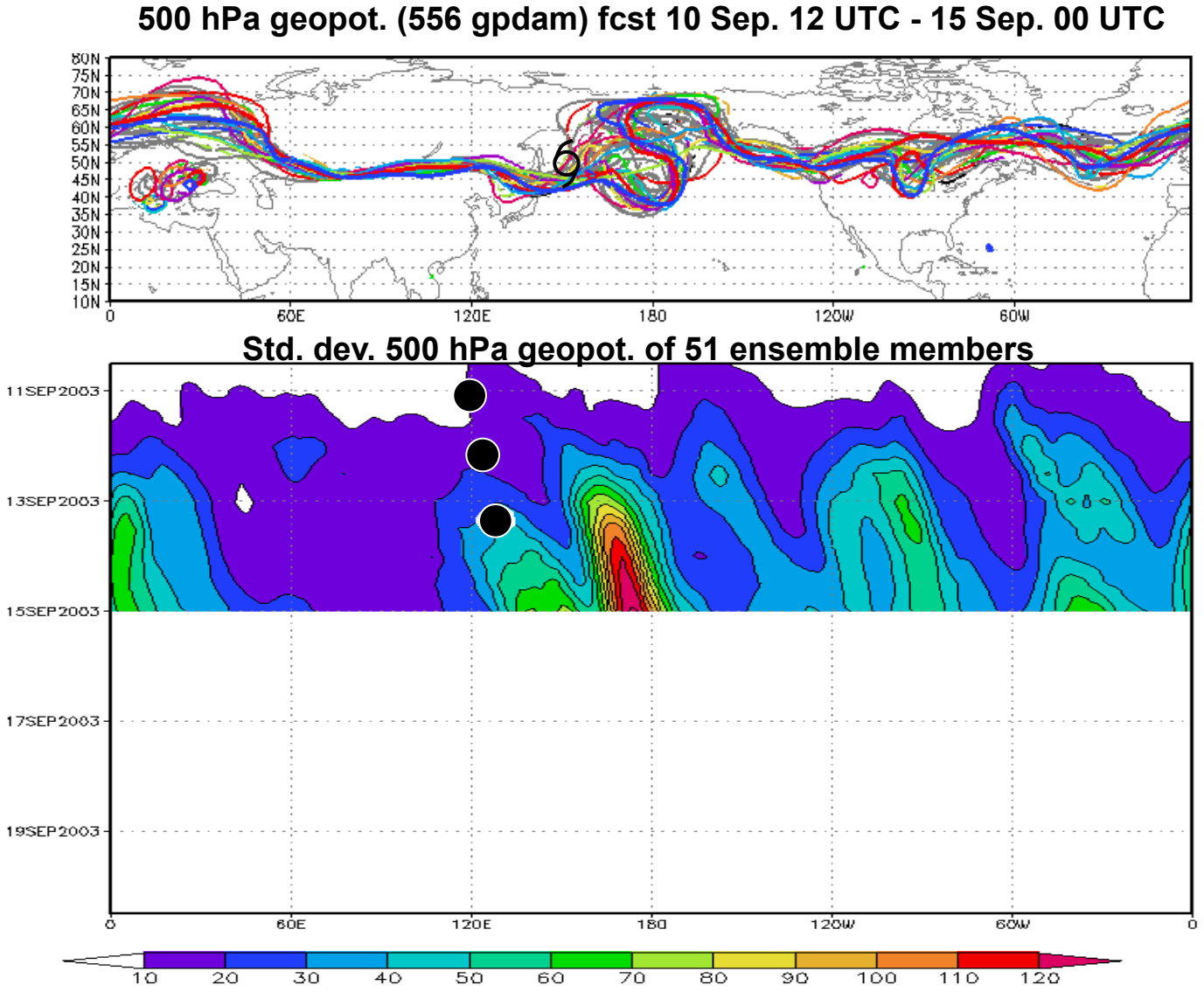

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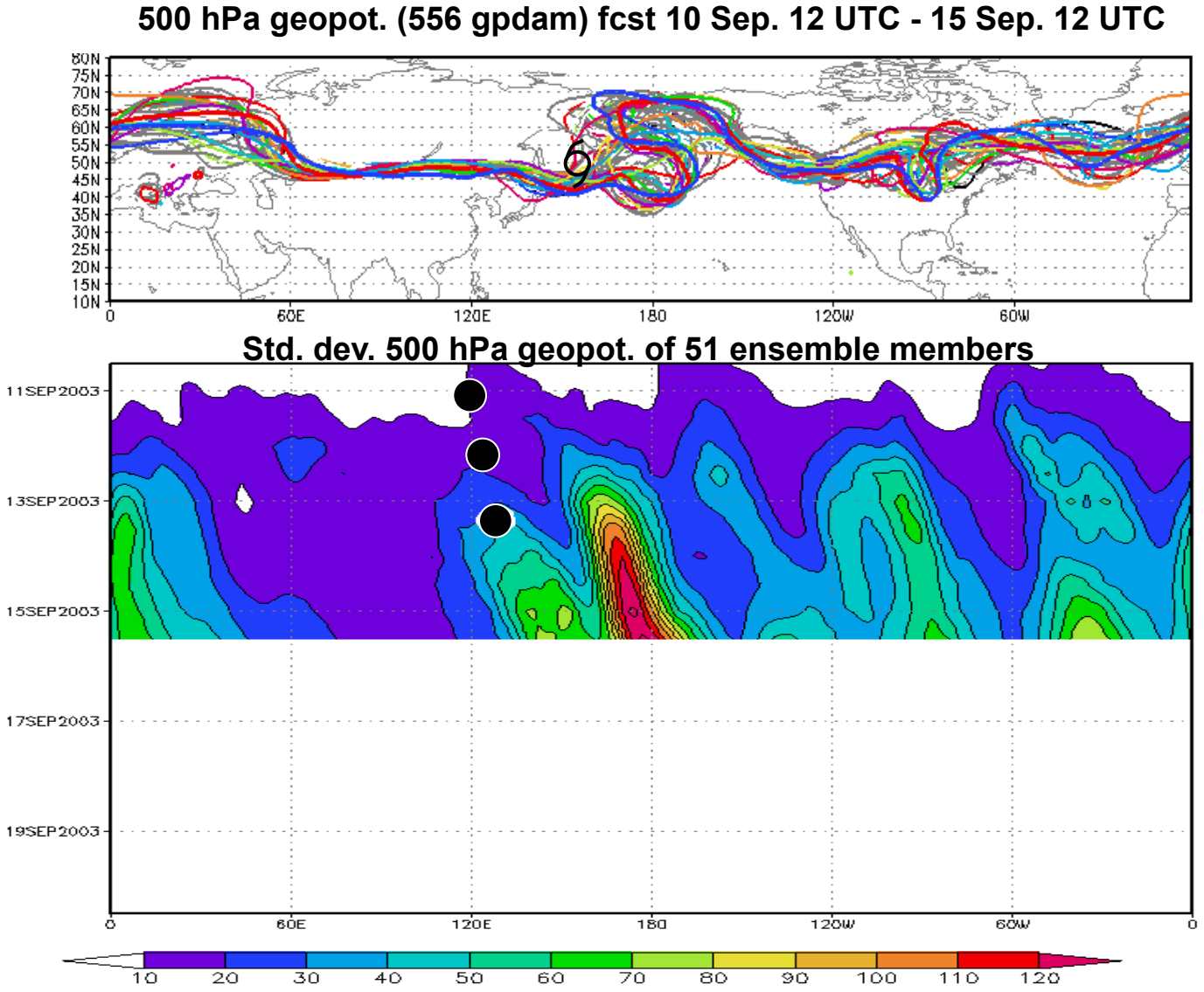

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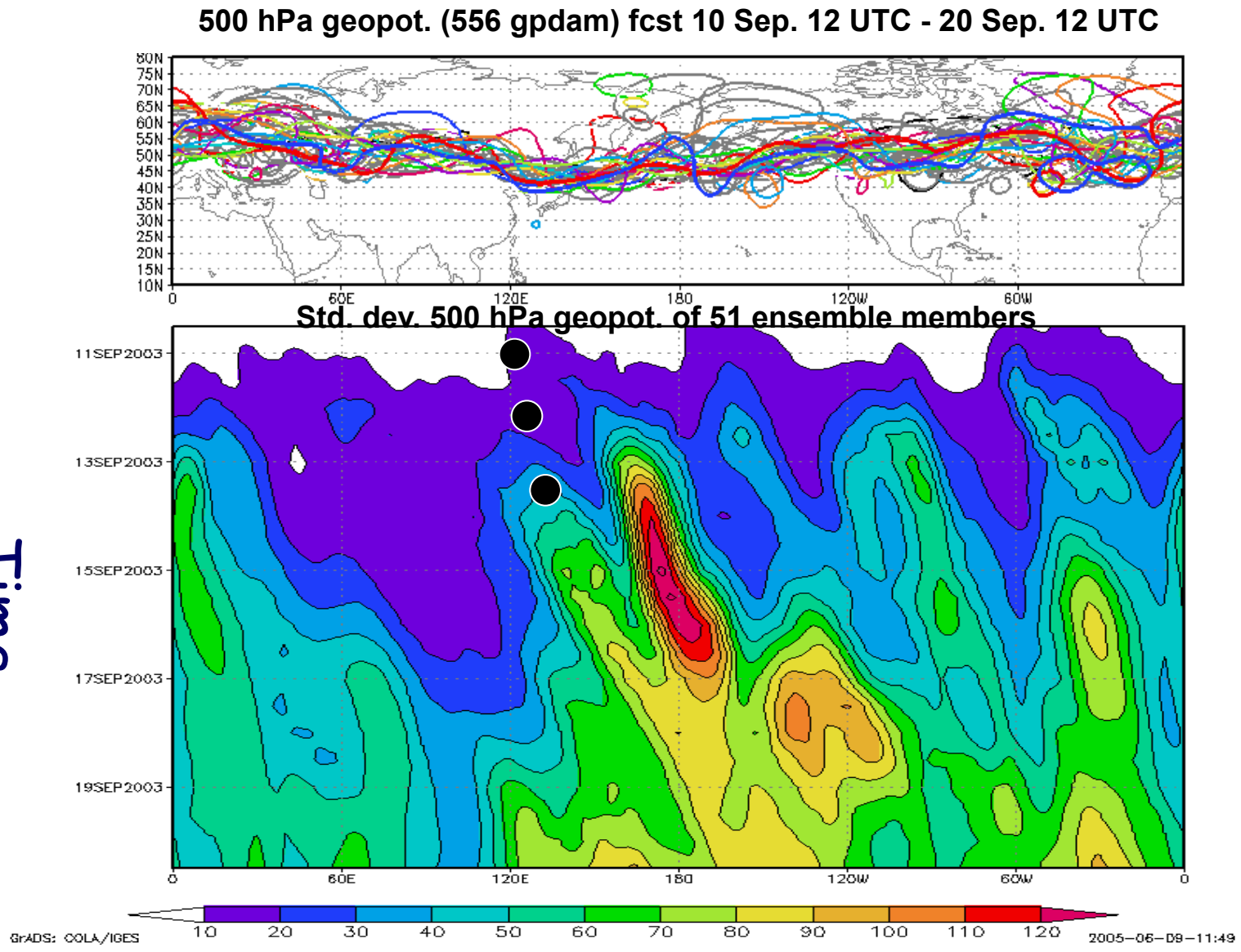
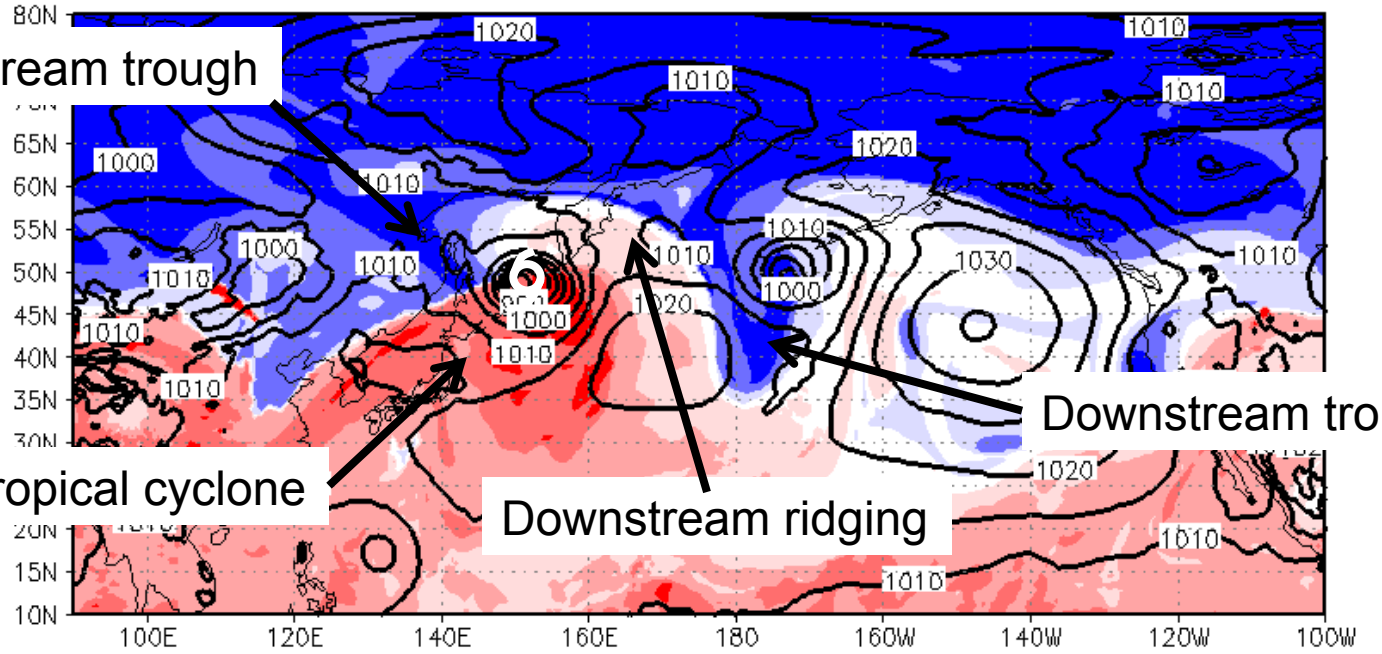


Characteristic development during Extratropical Transition (ET)

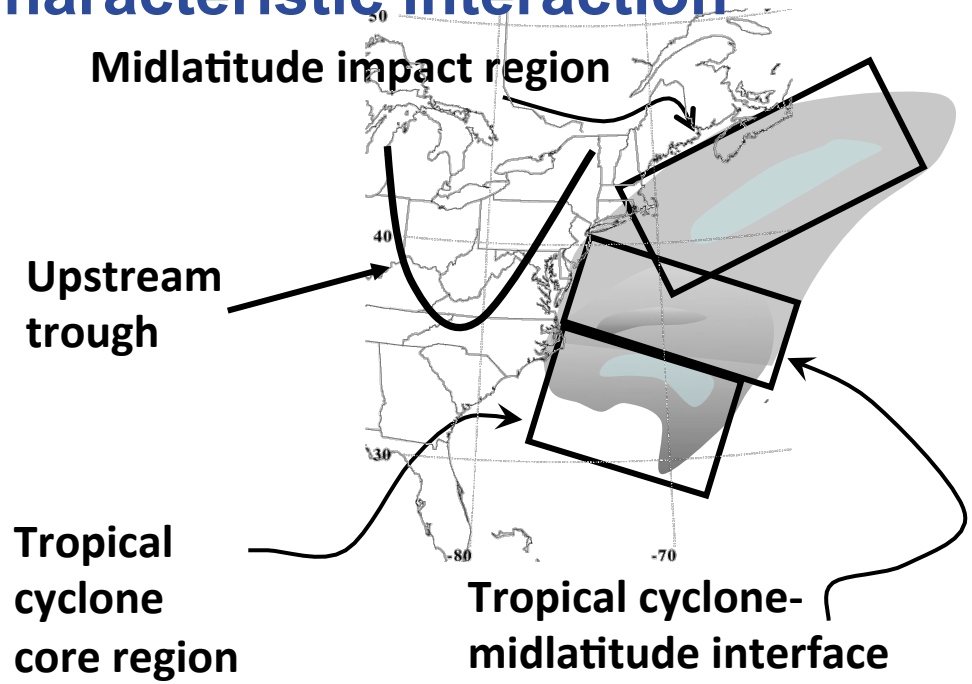
ECMWF analysis: 8 Sept. 2005 12 UTC

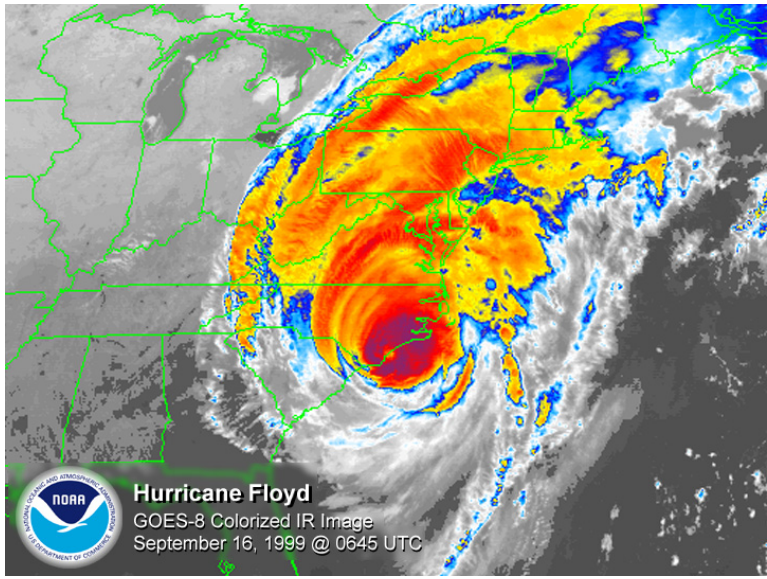


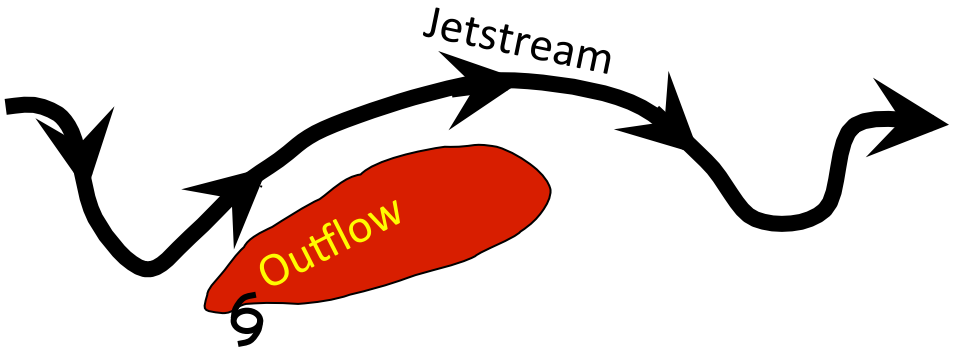
Typhoon Nabi (2005)

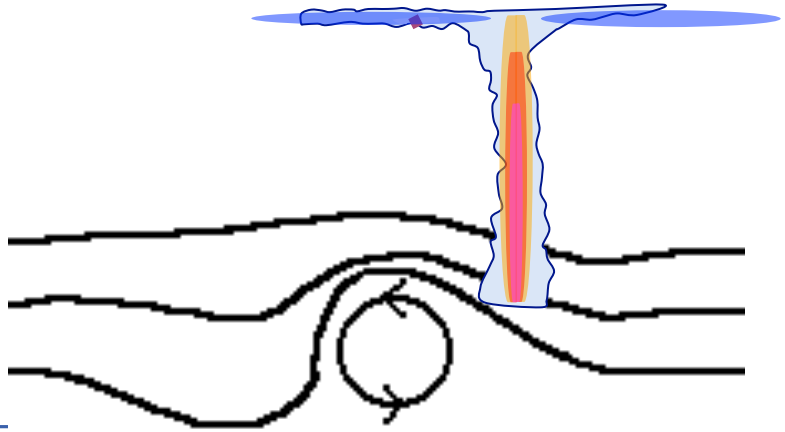
Colours: Tropopause Potential Temperature
Contours: Surface pressure

Characteristic interaction

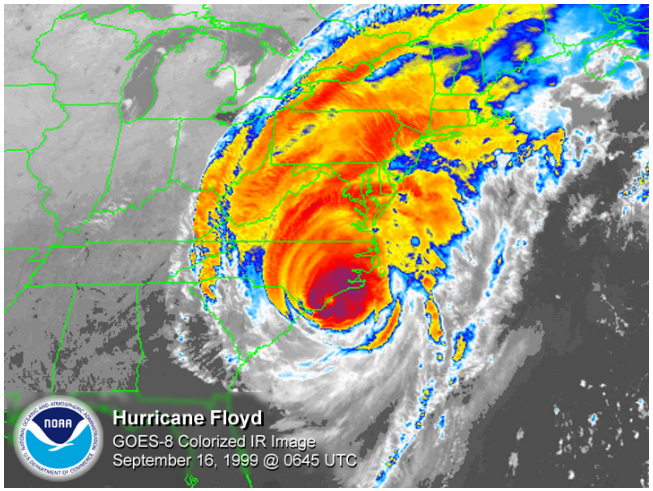




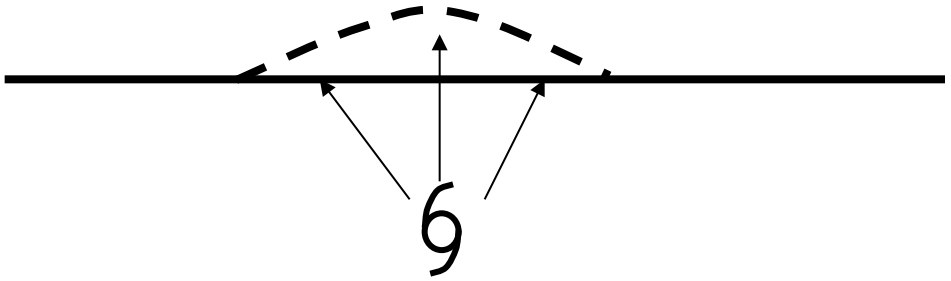




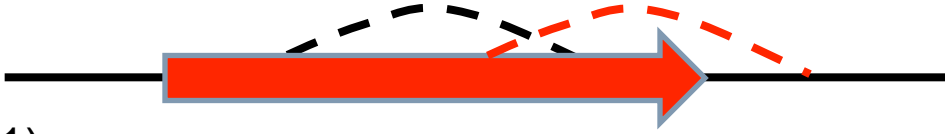
Excitation of a Rossby wave disturbance



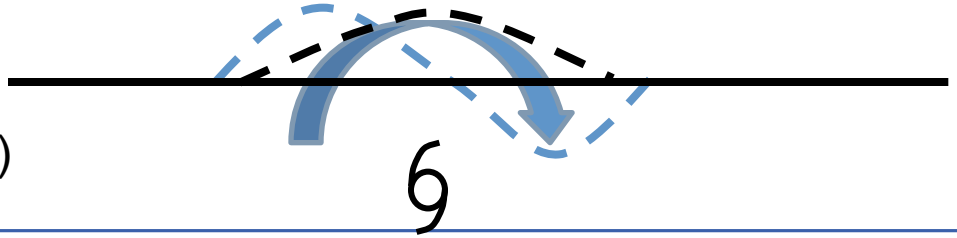
Divergent flow: ridge building



Jet: advects developing anomaly downstream



Flow assoc. with anomaly and TC
Anticyclone: westward propagation



Bosart and Lackmann (1995)
Henderson et al. (1999), Martius (2001)
Röbcke, Jones and Majewski (2004)
Riemer, Jones and Davis (2008)
Harr and Dea (2009)
Riemer and Jones (2010)
Scheck, Jones and Juckes (2010a,b)

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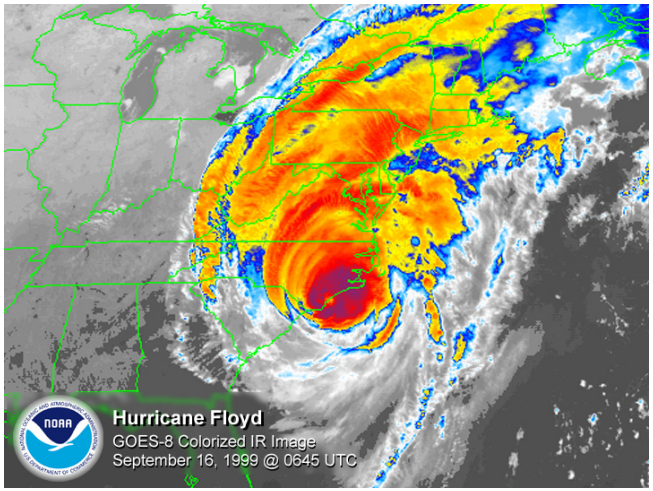
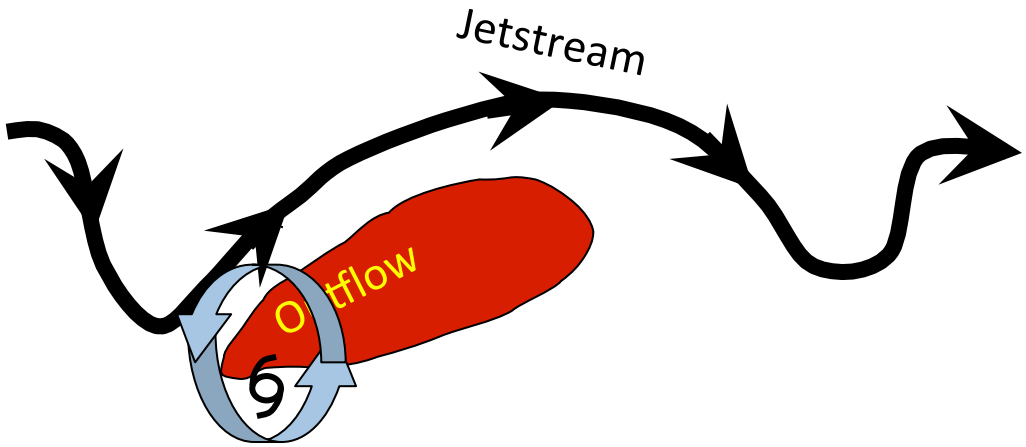
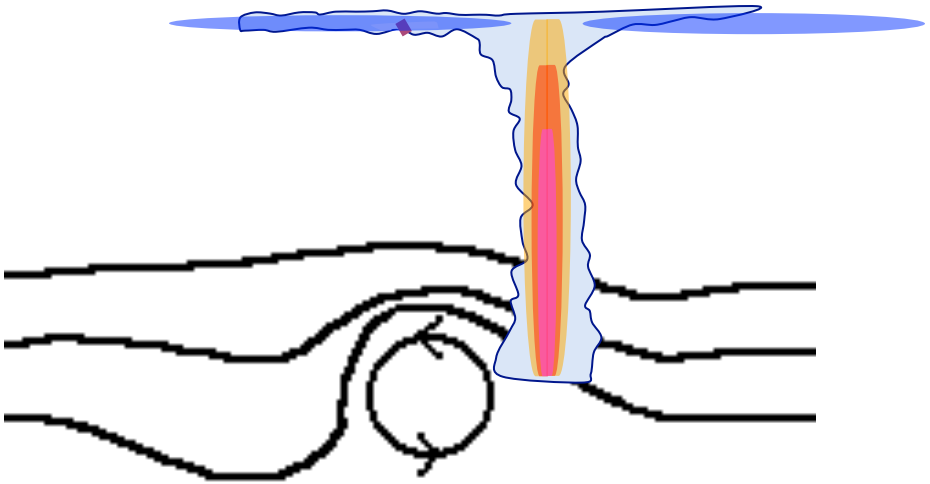
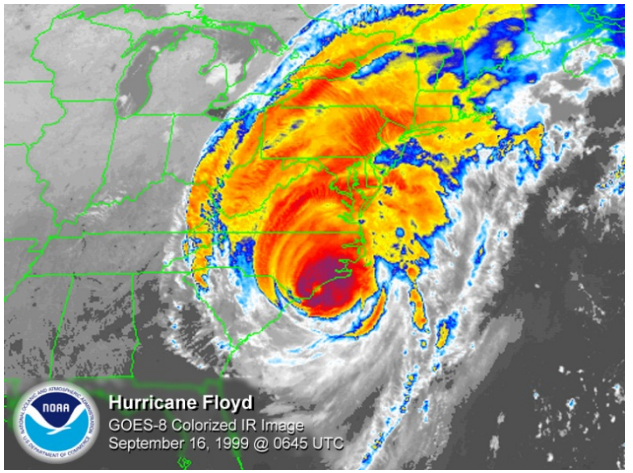




Cyclonic TC circulation enhances trough

Interaction with low-level baroclinic zone

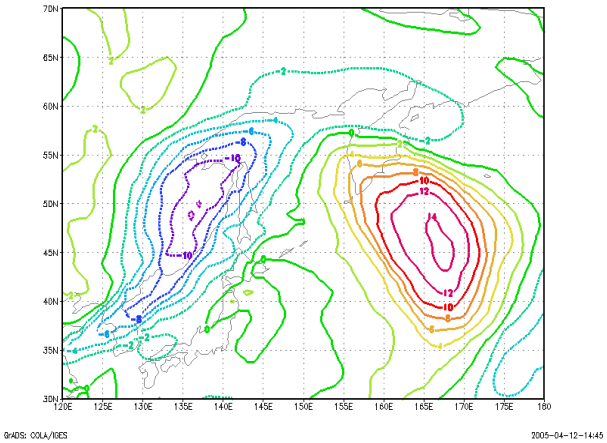




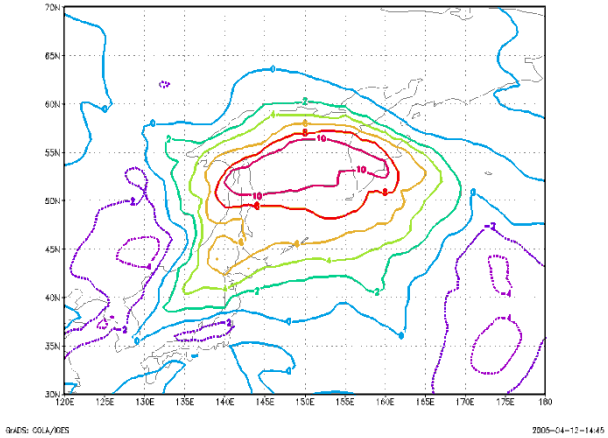
- Warm frontogenesis and upper-level ridge building (e.g. Bosart and co-workers, Harr and Elsberry 2000)
- Diabatic heating and new PV tower at warm front (e.g. Agusti-Panareda et al.)
- Polewards advection of moist air between TC and subtropical high (Torn 2010)
- Generation of diabatic Rossby waves

EOF-Analysis von Θ on PV = 2 pvu

EOF1 29.9 %

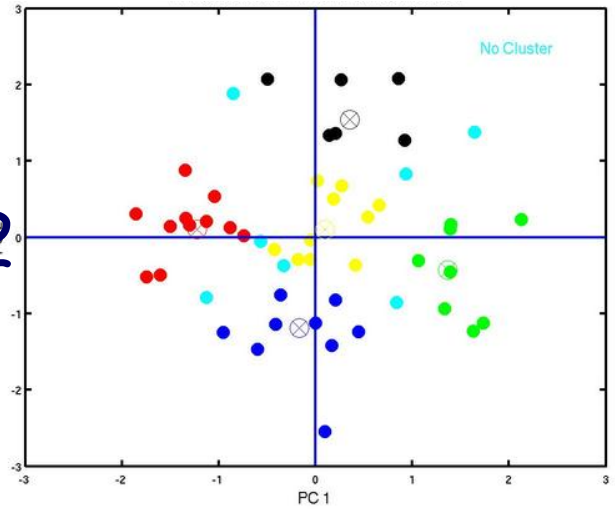


EOF2 19.0 %



EOFs identify synoptic-scale patterns that dominate variability

Principal Components give contribution of each ensemble member to EOFs



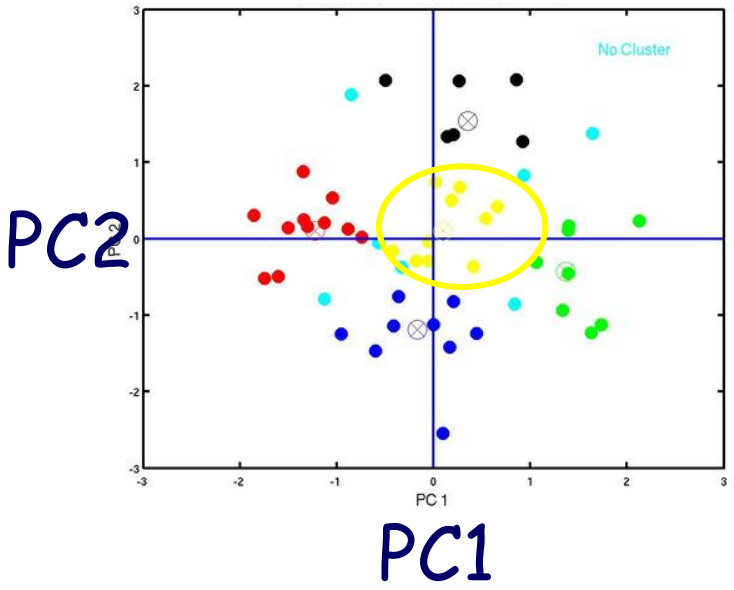
Forecast from 10.09.2003 12 UTC – 14.09.2003 00 UTC

2 main patterns of variability: shift / amplitude

Analysis method: EOF analysis & fuzzy clustering of principal components

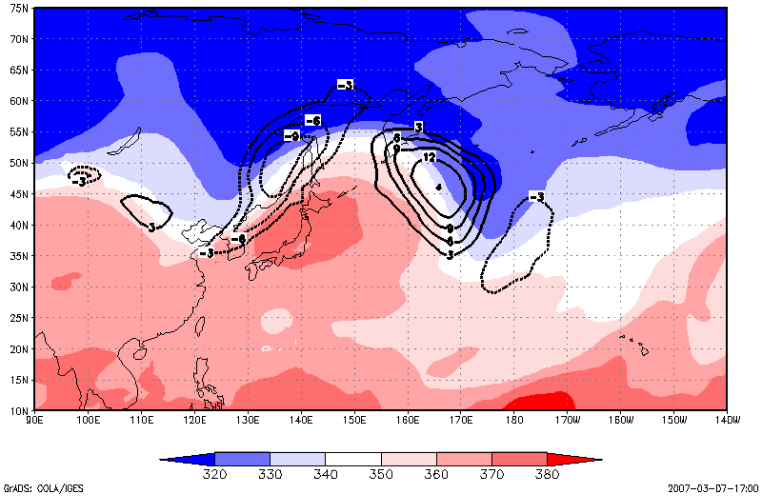
Fcst: 10 Sep. 12 UTC – 14 Sep. 00 UTC

Analysed variable: Potential temperature on dynamic tropopause

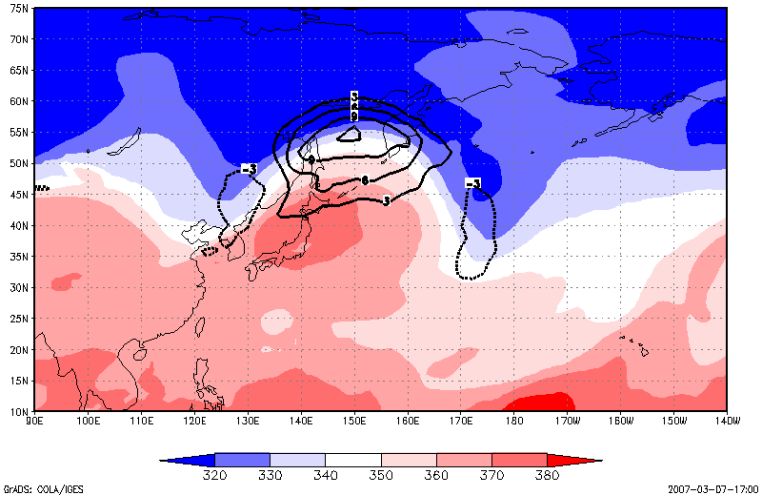


Anwender, Harr and Jones 2008

EOF 1 **18.9 %**



EOF 2 **11.5 %**



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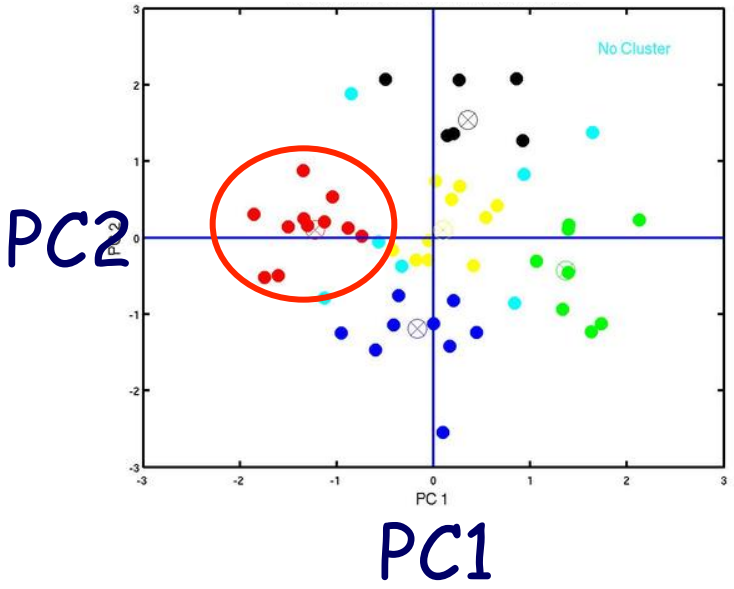

Anwender, Harr and Jones 2008

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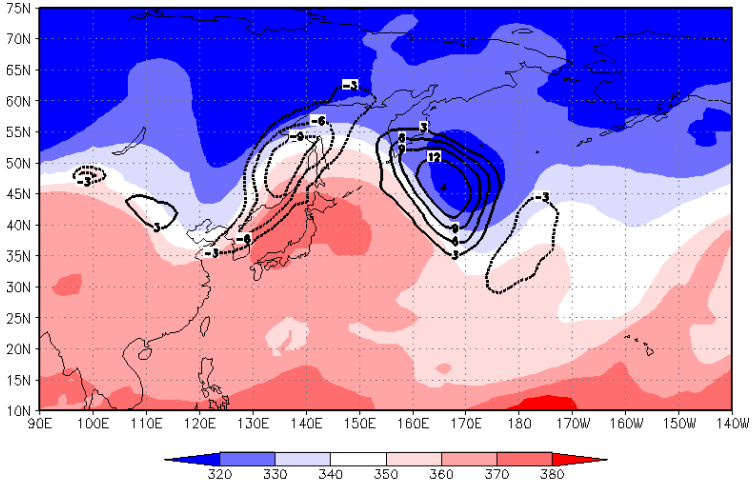
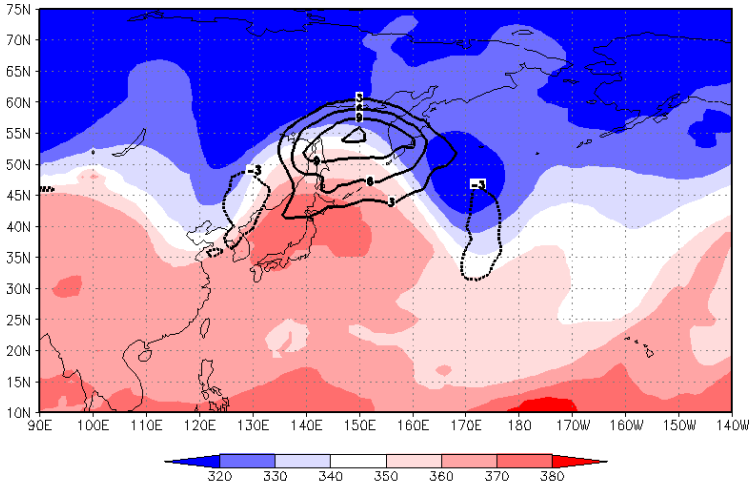


EOF 2 **11.5 %**



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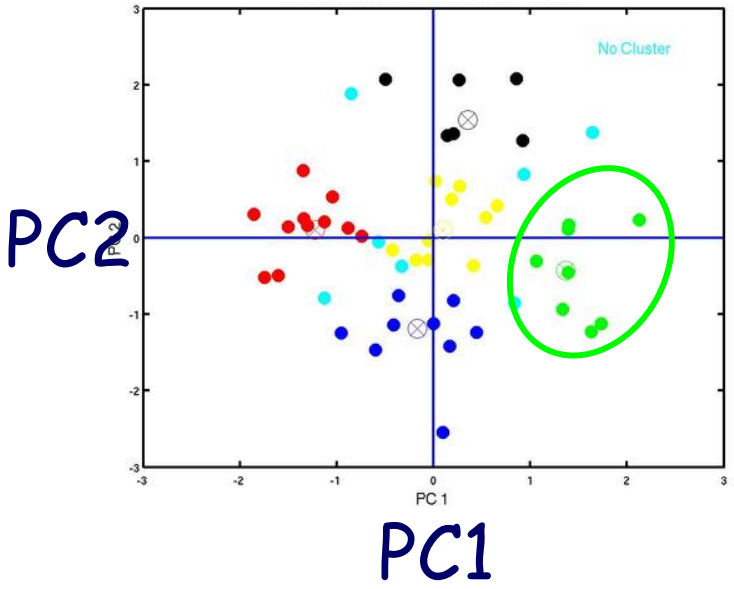

Anwender, Harr and Jones 2008

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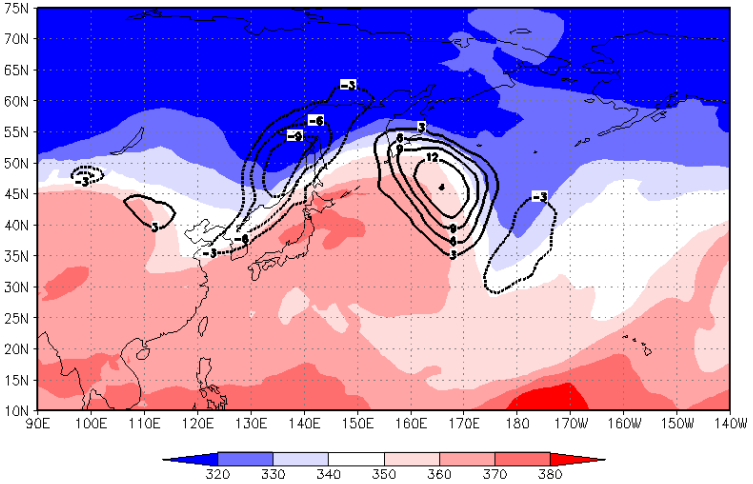

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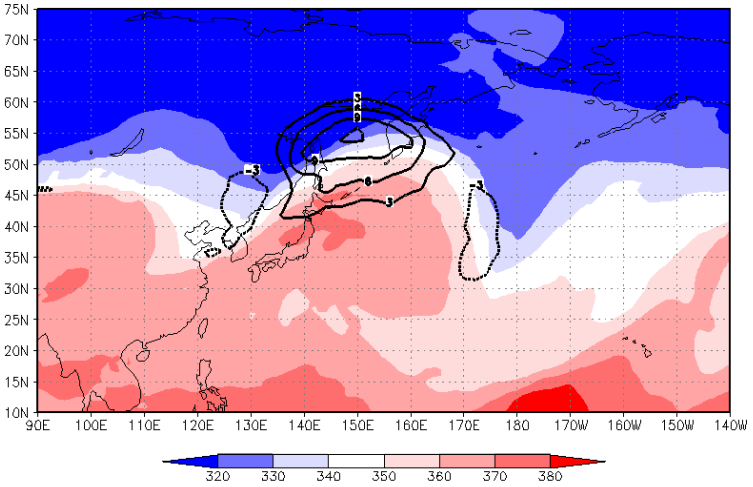

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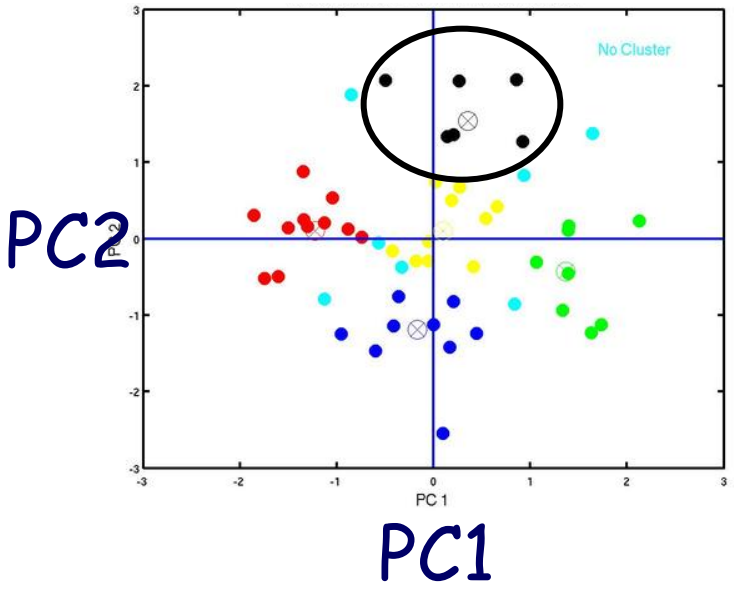

Anwender, Harr and Jones 2008

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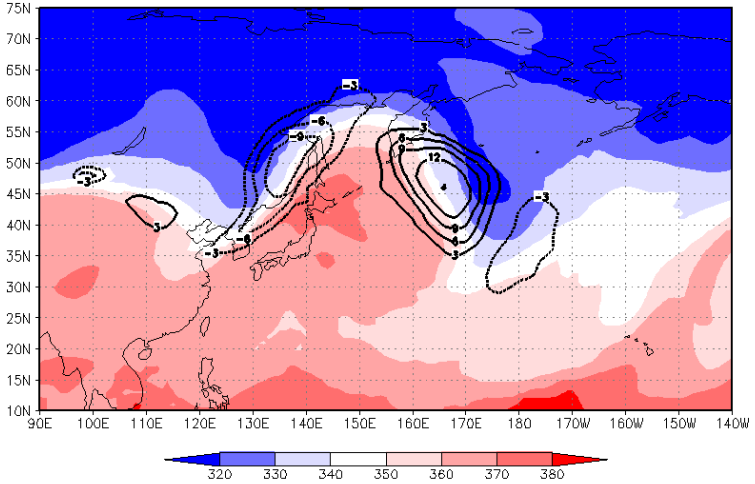
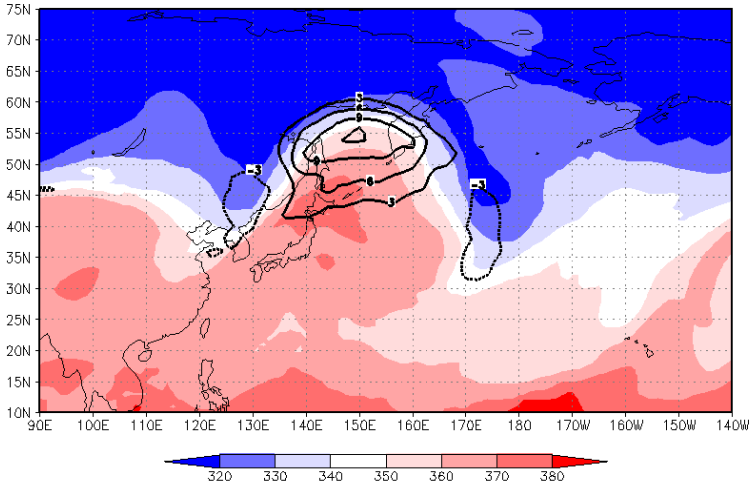


EOF 2 **11.5 %**



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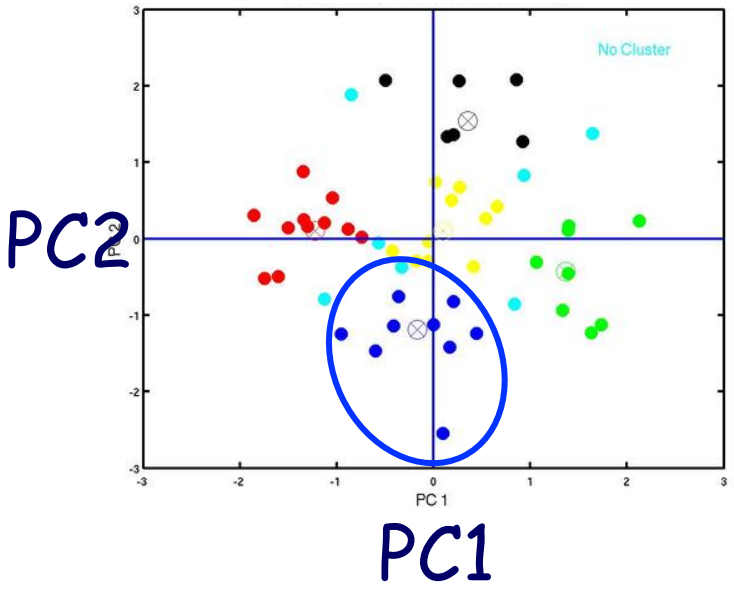

Anwender, Harr and Jones 2008

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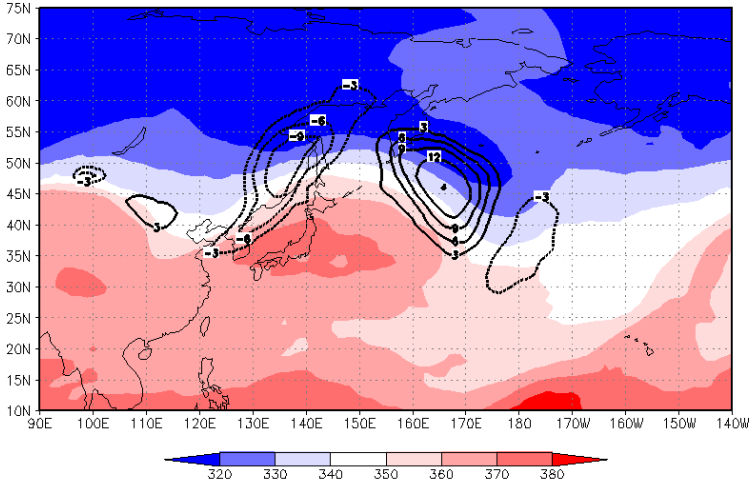
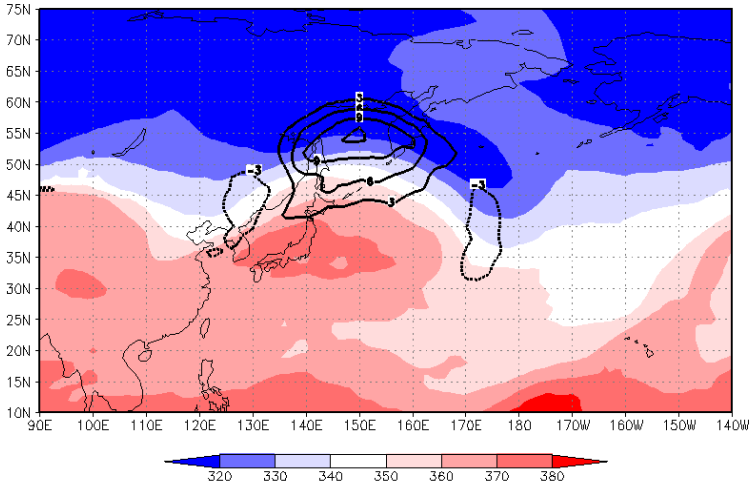
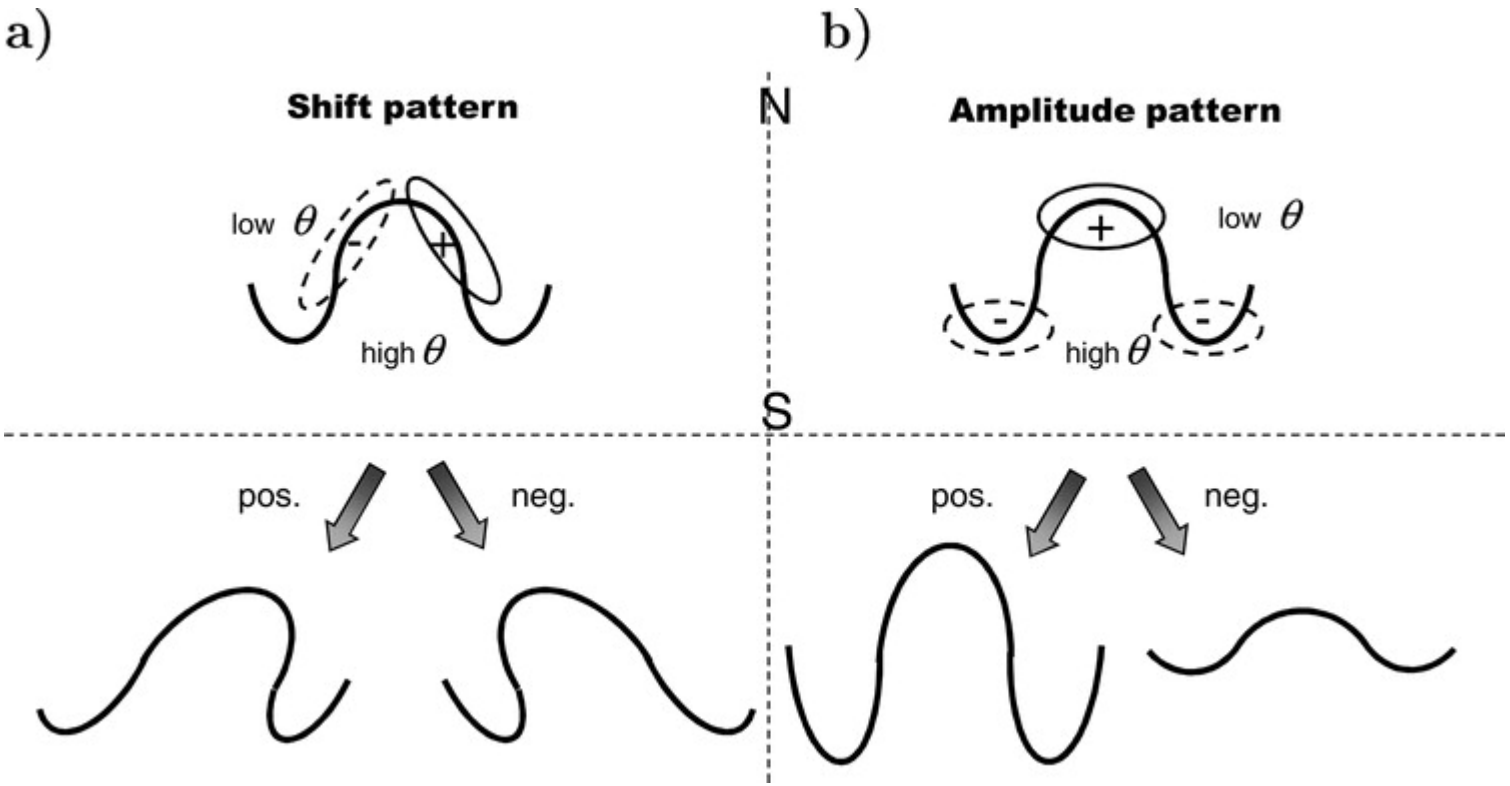


EOF 2 **11.5 %**

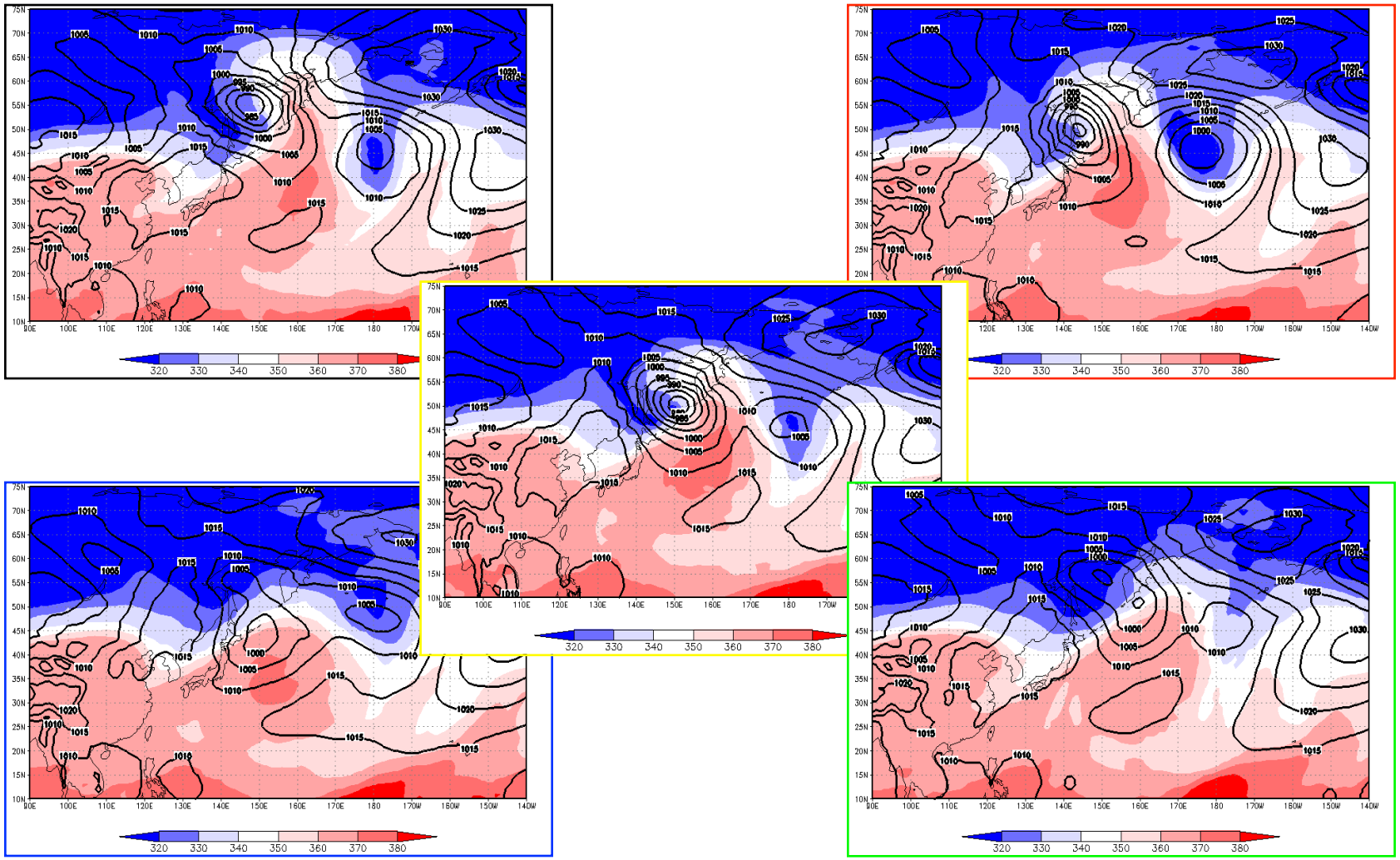




Anwender, Harr and Jones 2008

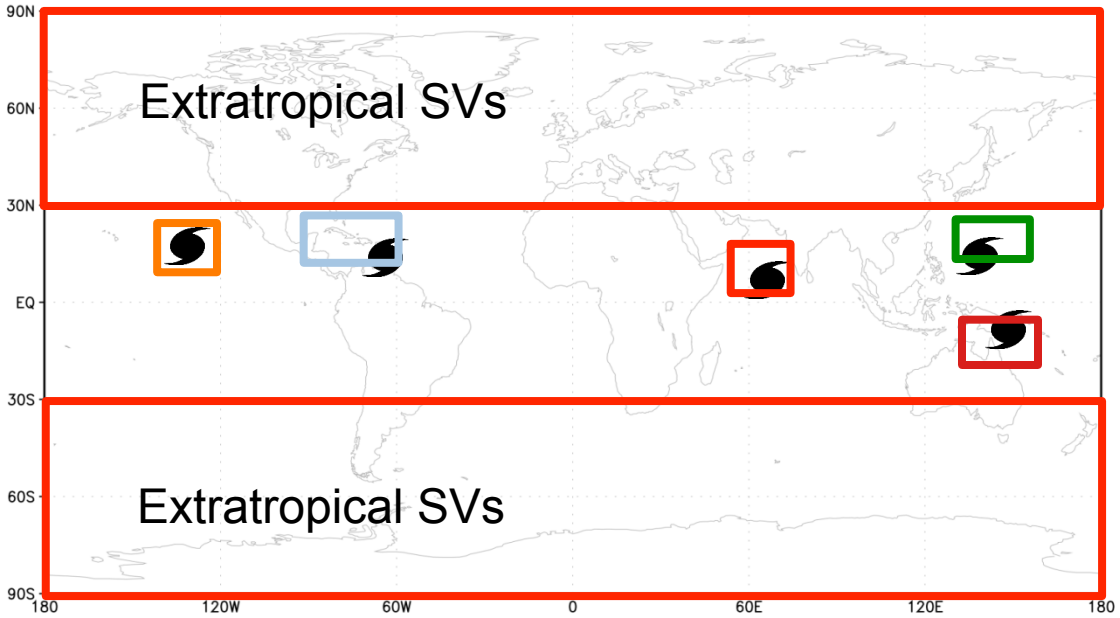
Tropopause pattern linked to development during ET

Potential temperature on dynamic tropopause (shaded) – surface pressure (contours)



Anwender, Harr and Jones 2008

Singular vectors in the ECMWF EPS

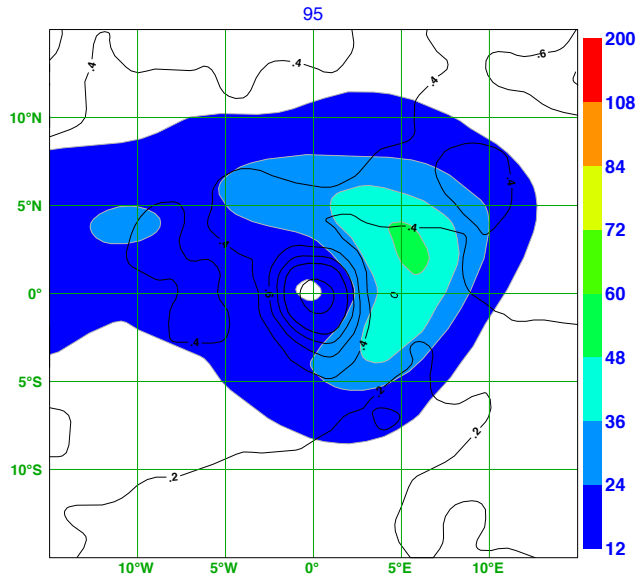


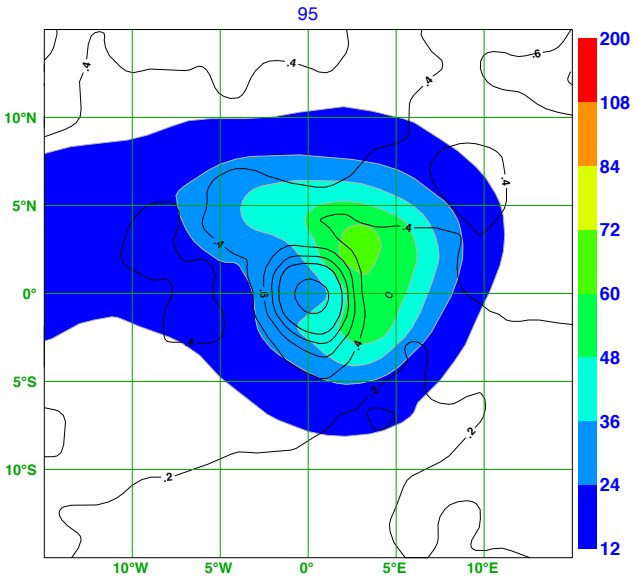
SVs identify the fastest-growing perturbations within a finite time interval in a linear framework.

To initialize the EPS SVs are calculated for different target regions with an optimization time of 48 hours.

Lang, Jones, Leutbecher, Peng and Reynolds (2012)

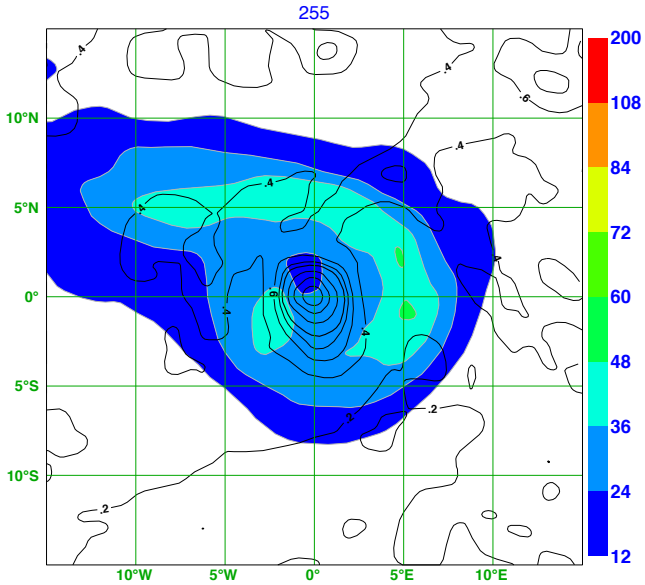
Dry TL95
≈ 210km

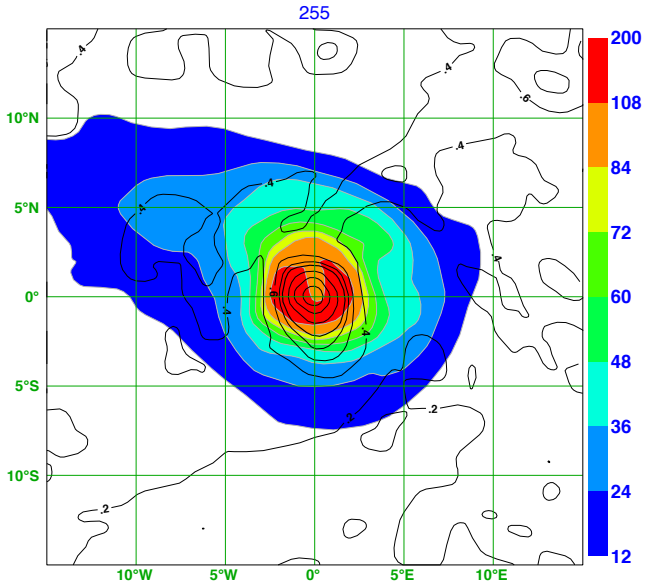




Moist TL95
≈ 210km

Dry
TL255
≈ 80km





Moist
TL255
≈ 80km

Lang, Jones, Leutbecher, Peng and Reynolds (2012)

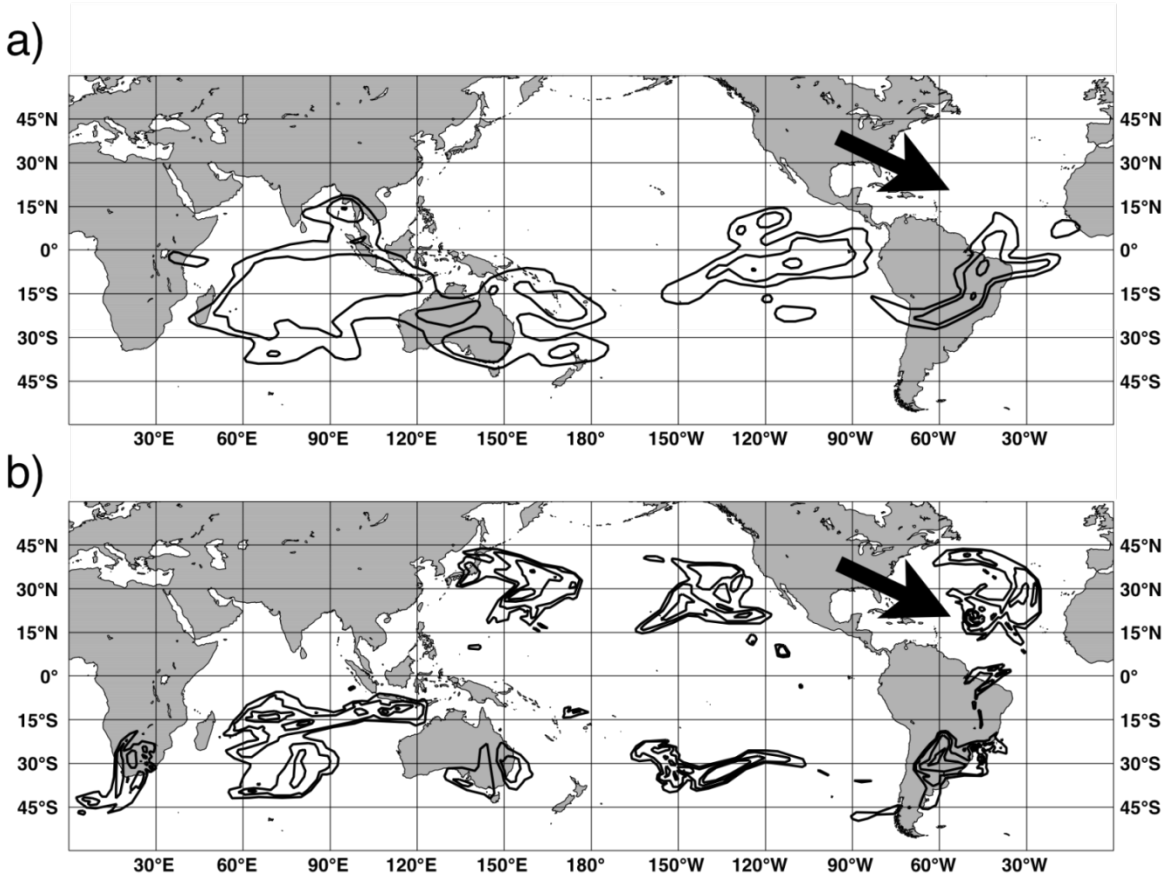
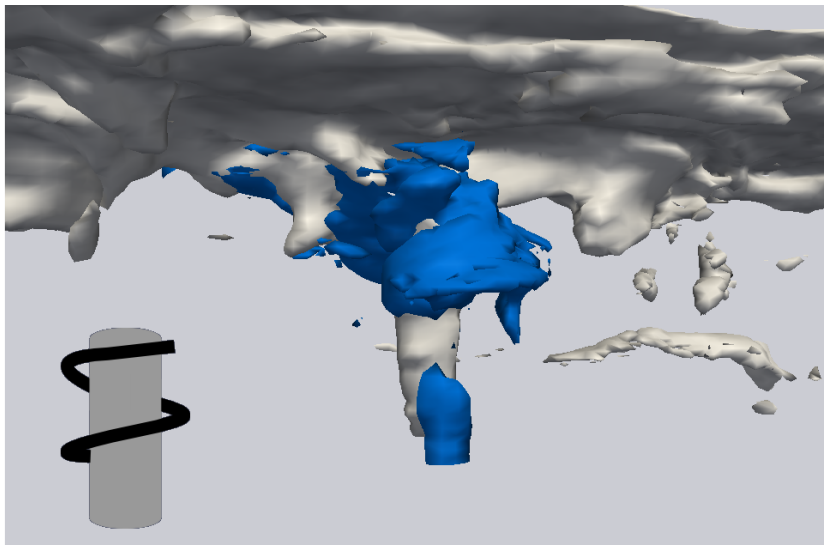


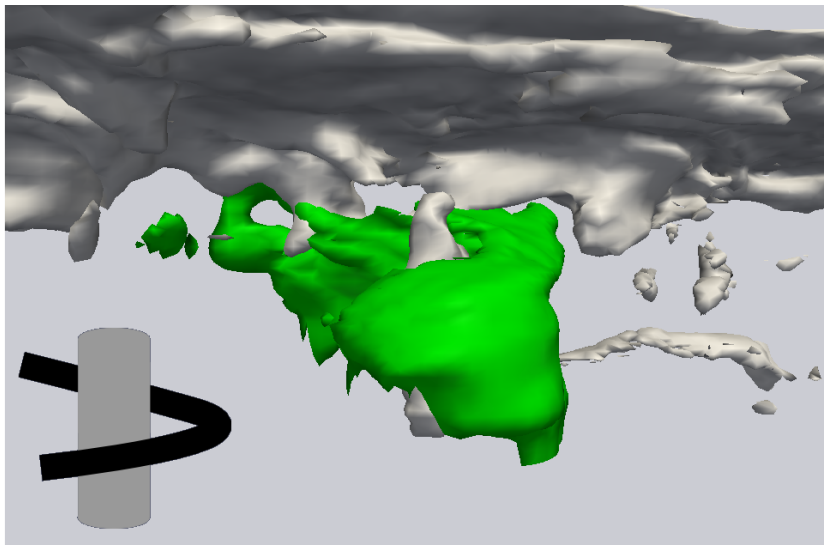
FIG. 5. Vertically integrated total energy (black contours) of the leading 20 initial SVs from 17 September 2006 12 UTC optimized for the tropical belt (30N to 30S). a) T42 SVs and b) TL255 SVs. Contour lines are drawn at 5, 10, 25 and 50 J kg^{-1}. The position of Helene is indicated by the arrow

Moist (TL255)

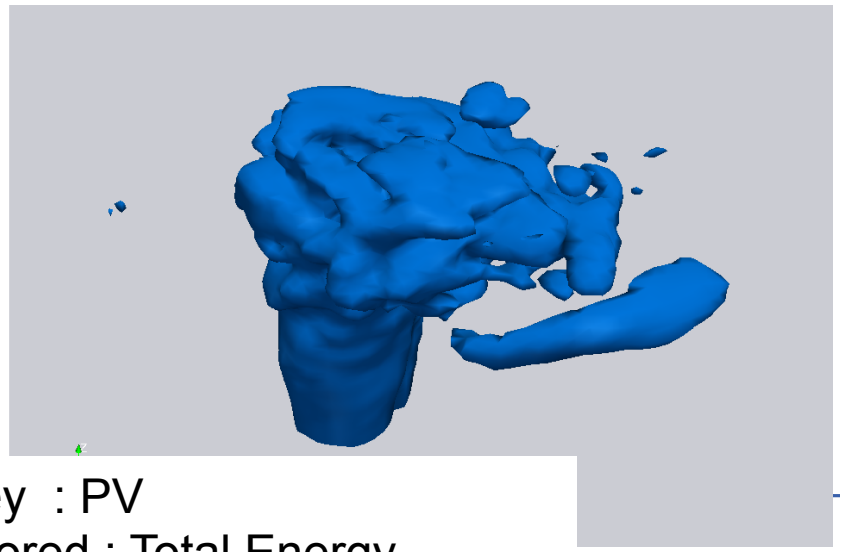
Dry (TL255)

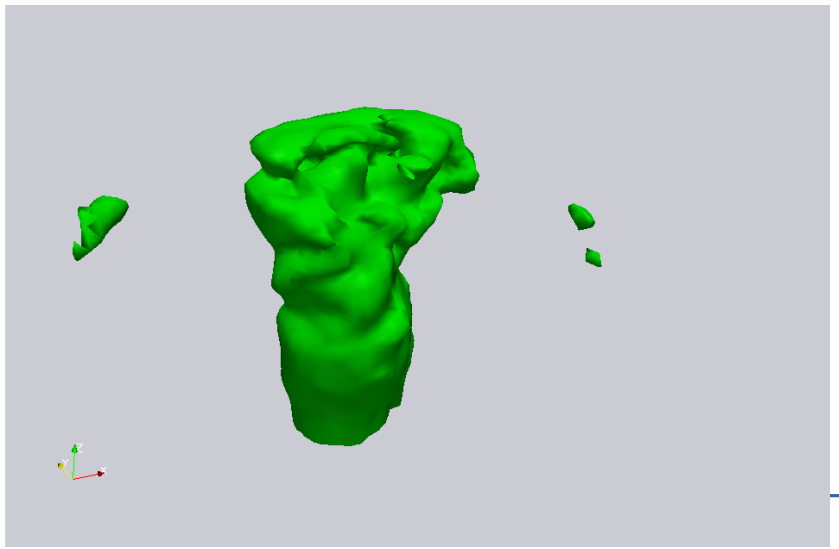
0 h





48 h

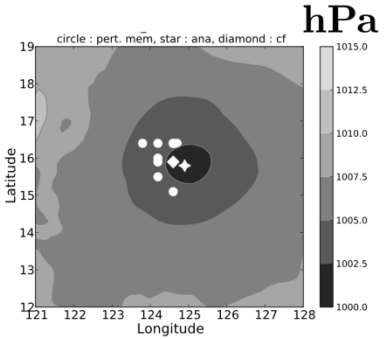




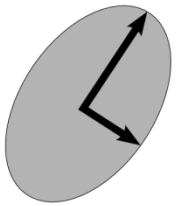
Grey : PV
Colored : Total Energy

Lang, Jones, Leutbecher, Peng and Reynolds (2012)

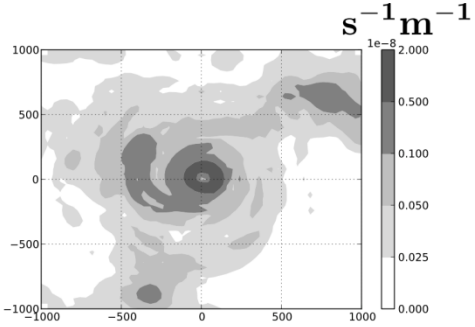
Methods used at ECMWF



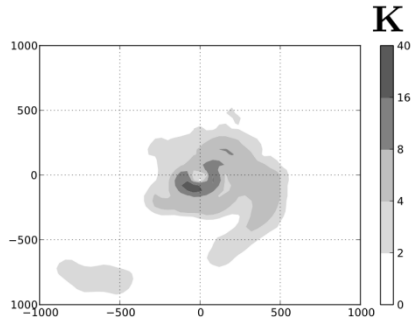
EDA



SVINI



SKEB



SPPT3

ANALYSIS UNCERTAINTY:

- Ensemble of Data Assimilations (EDA): ensemble of 10 4DVar with perturbed observations and stochastic physics

- Singular Vectors (SVINI): fastest growing perturbations (linear framework)

MODEL ERROR:

- **Stochastic Kinetic Energy Backscatter (SKEB)**: scheme to model e.g. errors by discretization

- Stochastic perturbations of parameterised tendencies (SPPT): scheme to model errors caused by parametrization of processes

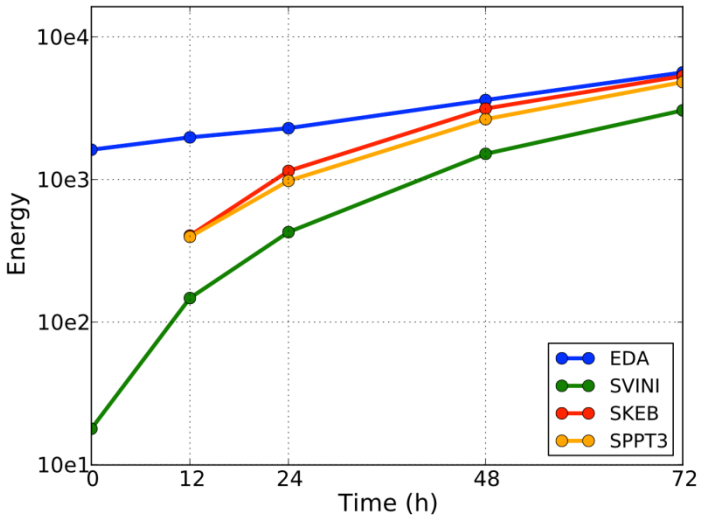
What impact do the different methods have on tropical cyclone forecasts?

Lang, Leutbecher, Jones (2012)

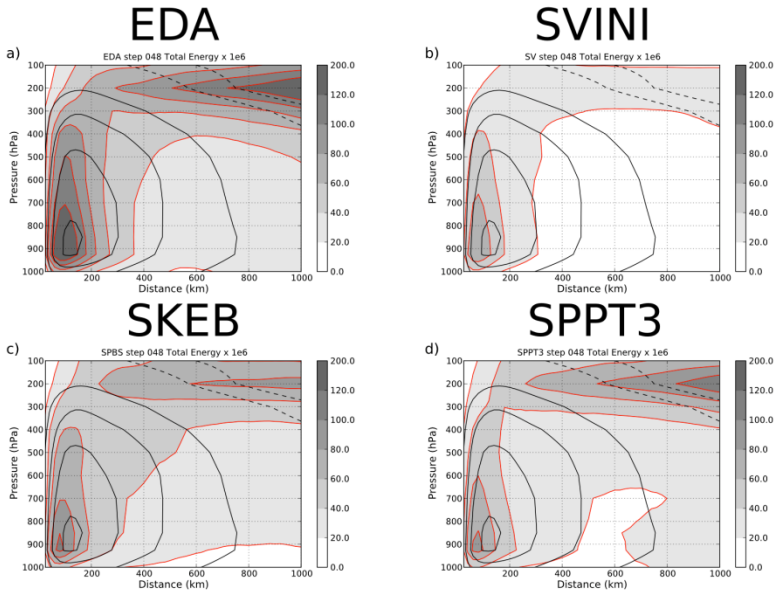
Experiments to quantify impact:

5 Different Ensemble Setups, 4 with only one perturbation method active -> equivalent to approx. **3500** individual **global weather forecasts** (30 km resolution, 62 vertical levels) and **1400** individual **4DVar analysis**.

Analysed perturbation growth and patterns for **13 tropical cyclone** cases:



Energy Growth



Azimuthally integrated perturbation energy after 48 hours

Lang, Leutbecher, Jones (2012)

TC track and intensity spread:

Ensemble using all four perturbation methods shows nice track error / spread correspondence

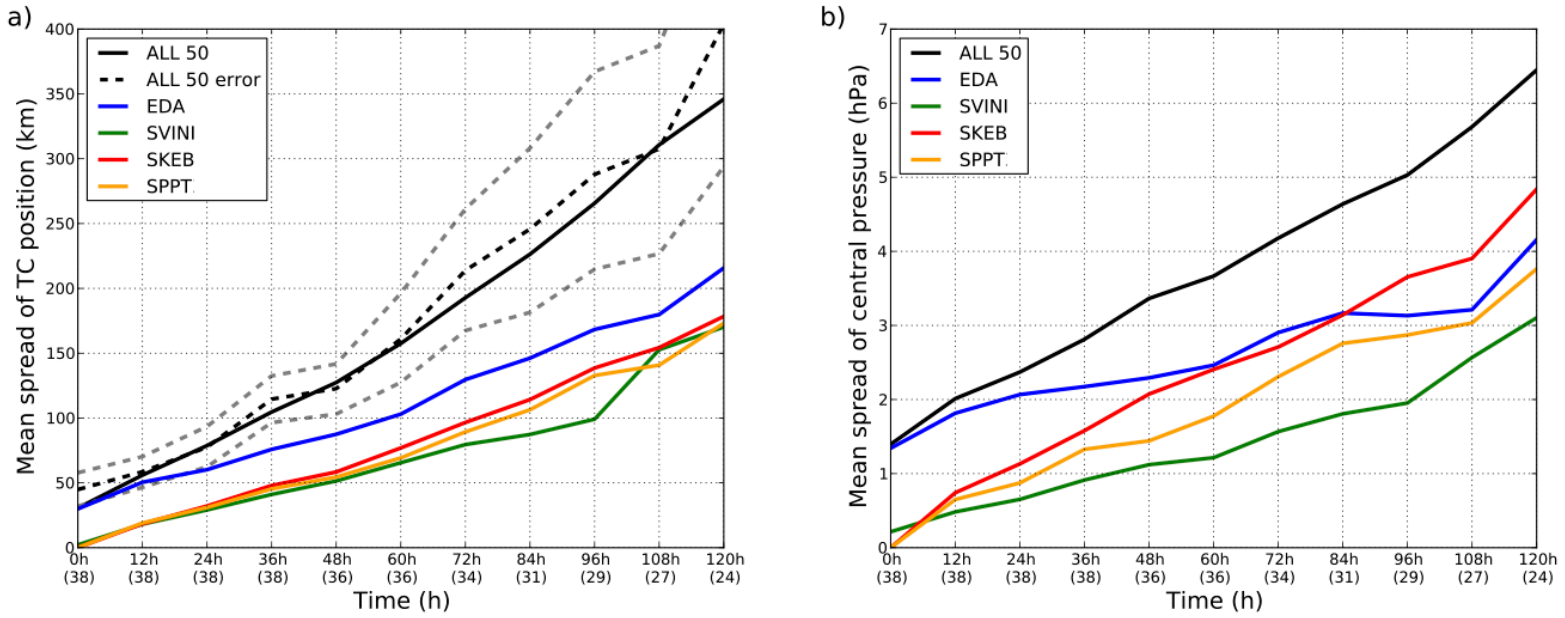


Figure 13. Mean ensemble spread of TC track (a) and central pressure (b) of the different ensembles. The dashed black line indicates the mean track error of the ALL 50 ensemble-mean. The dashed grey lines indicate the 95% confidence interval for the difference between mean error and mean spread of the ALL 50 ensemble. Hence if the black line lies within the range indicated by the grey dashed lines, we consider the differences not to be statistically significant. The numbers in parentheses indicate how many forecasts were considered for the respective lead time.

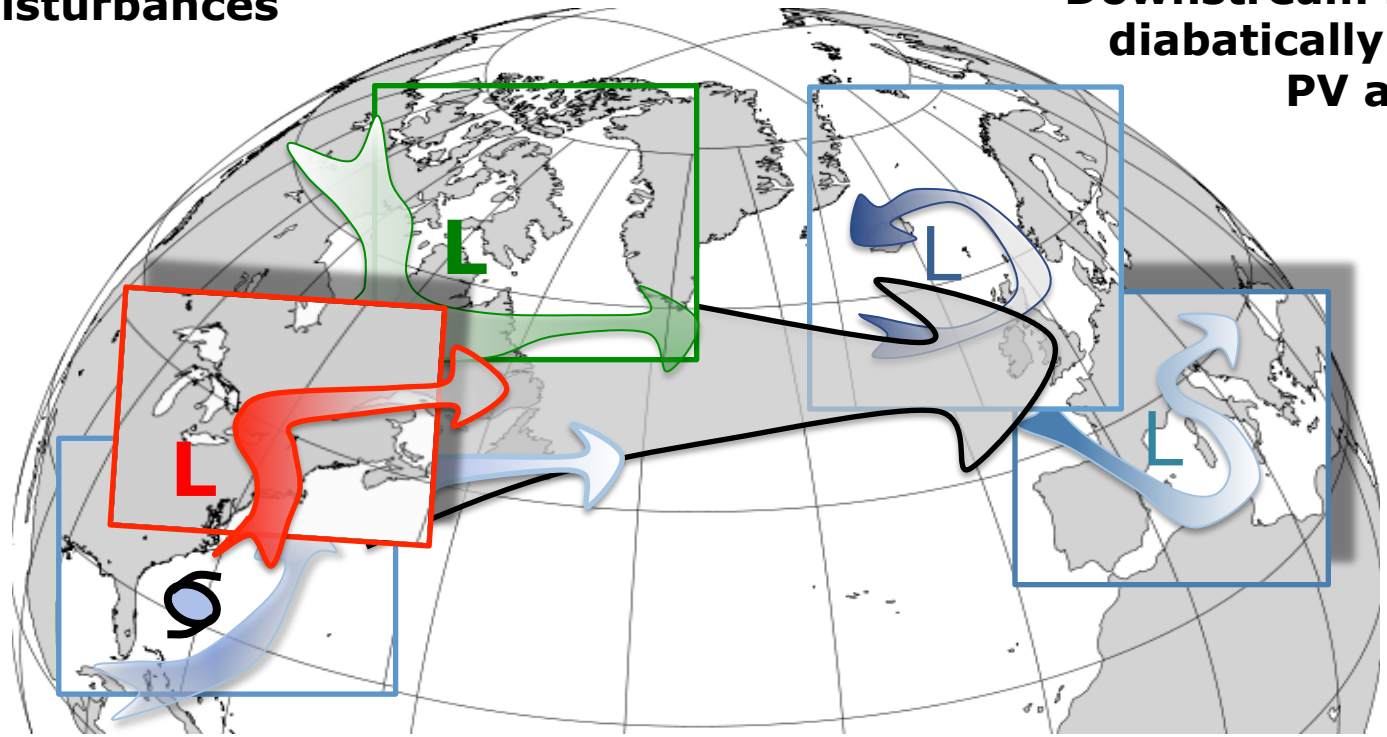
Lang, Leutbecher, Jones (2012)

T-NAWDEX/DOWNSTREAM 2016

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Factors modifying waveguide disturbances

Downstream impact of diabatically modified PV anomalies



Evolution of Rossby waves along the waveguide

T-NAWDEX/DOWNSTREAM 2016

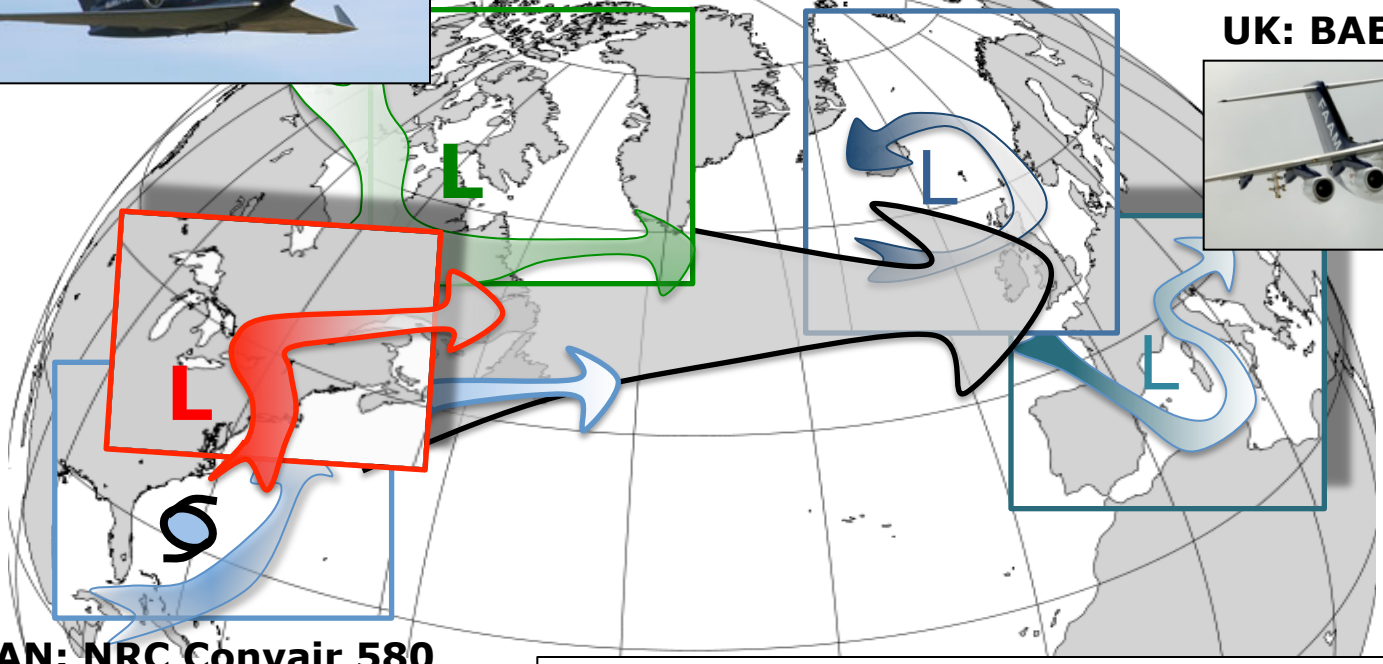
Ideal operation period in **Sep/Oct 2016:**

- strongest storm activity
- Tropical Cyclones
- Polar Vortices

GV: HALO

US: GV

UK: BAE 146

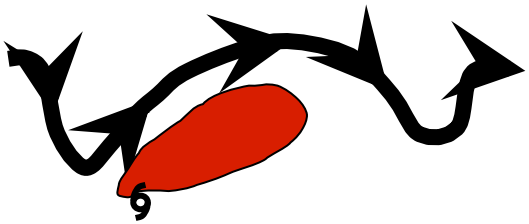


CAN: NRC Convair 580

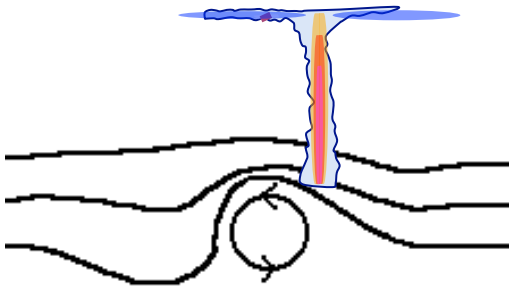
Partners

- Germany: DLR IPA, FX, KIT Karlsruhe, Univ. Mainz
- ETH Zürich
- US: NPS, NCAR, OU, Princeton, MIT, NOAA
- French, UK, CAN contributions envisaged
- Links to national weather services: DWD, ECMWF

Summary

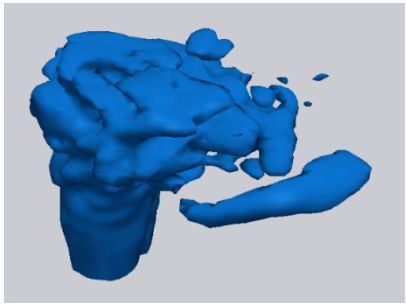


Interaction of tropical cyclones and midlatitude wave guide leads to excitation / modification of Rossby wave trains



Process often not well captured in NWP models

Advances in design of EPS allow for better quantification of uncertainty



Additional insight through T-NAWDEX / DOWNSTREAM & further NWP experiments